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ORIGINAL ARTICLES.

I.—On some Carboniferous Shale from Siberia.

By Professor T. Rupert Jones, F.R.S., F.G.S., etc.

(PLATE XVI.)

Introduction.

In December last M. J. Tolmatschow, Conservator of Geology in the Museum of the Imperial Academy of Sciences in St. Petersburg, sent for my examination a quantity of two fossiliferous shales from the (Upper?) Coal-measures in the Basin of Kousnetzk, thinking that specimens of *Estheria* might be found in them.

Both the shales came from sections on the Upper Ters River, a right affluent of the Tan River. From one locality (on the Toostooérr River) most of the shale, like that from the other locality (Boogtasch Mountain), is very flaky and friable; but some beds of the former constitute a hard and thick *Posidonomya*-shale.

Both shales are dark in colour, here and there somewhat bituminous, and accompanied by a film of coal in one specimen. The surfaces of the shale bear crowds of flattened valves of *Anthracomyæ* and *Posidonomyæ*, often much distorted by pressure, rarely keeping the shell, and usually presenting only a black shiny film.

Description of Specimens. (Plate XVI.)

No. I (Figs. 1–4).—This is a right valve, flattened and lengthened by pressure; obliquely ovate, nearly straight above, elliptically rounded below; higher behind than in front; extremities rounded; the posterior more produced than the anterior end, at an angle of 25°–30° with the superior border (hinge-line). Concentric lines thin and numerous.

These features seem to agree with some of Dr. W. Hind's figures of *Anthracomya minima* (Ludwig), as published in his Mon. Pal. Soc., 1895, pt. ii, p. 116, pl. xvi, figs. 21, 22, 24–30. Fig. 23 is referred (perhaps wrongly) to a variety of *A. lævis*, Dawson, but has much of the appearance of *A. minima*.

Posidonomya membranacea, McCoy (Synop. Carb. Foss., p. 78, pl. xiii, fig. 14), is an elongate form with delicate concentric lines; but it is larger, and differs in shape from Fig. 1; it also has some longitudinal lines crossing the others. *P. lateralis*, Sowerby & Phillips, is also one of the obliquely elongate species, but it is much larger, and it has coarse concentric wrinkles.

No. II (Figs. 6 and 7).—This right valve is evidently allied to the foregoing, but has proportionately less length, a fuller convexity of the postero-inferior margin, and a greater obliquity, at an angle of 40° with the hinge-line. This may probably belong to *Anthracomya lævis*, Dawson.

No. III (Fig. 5).—This is a left valve, having features similar to those of Figs. 6 and 7, but much more pronounced. The obliquity is 65° instead of 40°. The hinge-line is short, and the postero-inferior margin is elongate-elliptical. The concentric lines are not so neat. This is possibly a *variety* of *A. lævis*, modified by pressure.

No. IV (Figs. 16, 17).—This left valve has a much more truly rounded inferior margin than that of Fig. 5, and approximates to a semicircle; its obliquity to the hinge-margin is greater (75°). It may be compared with some of the figures of *Anthracomya Valenciensis*, R. Etheridge, jun., given by Dr. W. Hind (Mon. Pal. Soc., 1895, p. 113, pl. xvi, figs. 44–48).

No. V.—Figs. 8–15 are subovate *Posidonomyæ* (*P. subovata*), having the umbo either more or less excentric or just in the middle of the hinge-line. They have a nearly semicircular inferior margin, and numerous concentric lines, ridgelets, or rugulæ. Fig. 10 has the umbo near the middle of the upper margin; and is very similar in shape to *Posidonomya punctatella*, Jones, from a Lower Carboniferous shale in Western Scotland. It measures 8 mm. transversely, by 6 mm. in height. Many larger valves, found in the same shales, having a similar shape, but with fewer and stronger concentric ridges, have been regarded as adult individuals, measuring 32 × 22, 30 × 18, 29 × 22, 28 × 20, 20 × 11, as I was informed by my old friend the late Dr. J. Young, of Glasgow, who sent me many sketches of them, with strong concentric ridges and nearly semicircular valves. These shales, especially at Dalry in Ayrshire and Thornliebank near Glasgow, bear crowds of *Posidonomyæ*, concentrically ribbed, oblong-ovate in shape, mostly equilateral, with more or less median umbo and semicircular inferior margin. Among them, at Linn Spout,[1] Dalry, and at Arden quarry, Thornliebank, occurred the *P. punctatella*, Jones,[2] once regarded as an *Estheria* (1869), but afterwards proved to be a *Posidonomya* (1890), and it is

[1] For a section of the Upper Linn limestone and *Posidonomya* bed of the Lower Carboniferous Series at Linn Spout, see the Mon. Brit. Pal. Phyll., Palæont. Soc., 1899, pt. iv, p. 208.

[2] Trans. Geol. Soc. Glasgow, 1867, vol. ii, p. 71, pl. i, fig. 5; 1890, vol. ix, pp. 85–87, pl. v, fig. 7.

well-matched in shape by our Fig. 10; but the latter is destitute of the punctate ornament, and the former may be the young form of a different species (*P. subovata*, nov.).

The shell-structure in our specimens is not pitted nor clearly prismatic, but is full of delicate lines of fissure, parallel with the thick, radiating breakages, corrugations, or pressure-folds; and causing the shell to come away in subquadrangular pieces, which are variously modified by decomposition before they are quite removed from the internal cast. The straightness of the microscopic fissures, and the regular edges of the separated pieces of the shell, may be due to the presence of a crystalline or quasi-prismatic structure not otherwise indicated.

In Figs. 8–15, as also in Figs. 5–7, the vertical markings crossing the concentric lines and riblets are due to pressure reducing the convexity of the original shell.

P. corrugata, R. Etheridge, jun. (Geol. Mag., 1894, p. 304, Pl. XIII, Figs. 4–6), occurring in the same shale at Linn Spout,[1] has a distant relationship with *P. punctatella* and *subovata*. Its concentric lines, however, are crossed by rough crumplings; and in its shape it differs from the other. Its variable and coarse radial lines are evidently regarded by the author as congenital, like the vertical ribs in *P. costata*, McCoy (Synop. Carb. Foss., p. 78, pl. xiii, fig. 15), and, if the figures which he gives are of the natural size, *P. corrugata* is much larger than Figs. 8–15.

No. VI. Fig. 18 (*Posidonomya concinna*, nov.).—This is part of a larger *Posidonomya*, with numerous, distinct, narrow, concentric ridges, with smaller parallel lines between. There are more perfect specimens of this rotundo-ovate form in the collection, measuring 18 mm. vertically and 20 mm. transversely.

This is characteristically abundant in some of the more solid shale at the Toostooérr River, accompanied by small *Posidonomyæ* and numerous obscure organic fragments.

No. VII (*Beyrichia Kirkbyana*, nov.).—Scattered throughout the shales, especially those from the Boogtasch Mountain, are numerous specimens of a small *Beyrichia*, about 1 mm. long.

It is characterized by the two moieties of the valve being always swollen, and separated by a dorso-medial sulcus, within and on one side of which is a little tubercle; and the whole surface is neatly reticulate.

This little Entomostracon is related to other Carboniferous *Beyrichiæ*, such as *B. impressa* (McCoy) and *B. cratigera* (G. S. Brady).

I propose to dedicate it to my lately deceased friend and fellow-worker James Walker Kirkby, for whose work among the minute fossils of the Carboniferous and Permian Series geologists owe great thanks.

[1] Catal. West. Scot. Fossils, 1876, p. 52.

EXPLANATION OF PLATE XVI.

FIG. 1.—*Anthracomya minima* (Ludwig), Hind. Right valve. Natural size, 10 by 5 mm.—Fig. 2, magnified.
,, 3.—*A. minima* (Ludwig), Hind. Right valve. Natural size, 13 by 8 mm.—Fig. 4, magnified.
,, 5.—*A. lævis*, Dawson. Variety. Left valve, magnified. Natural size, 8 by 6 mm.
,, 6.—*A. lævis*, Dawson. Right valve. Natural size, 7 by 5 mm.—Fig. 7, magnified.
,, 8.—*Posidonomya subovata*, sp. nov. Left valve. Natural size, 7 by 5 mm.—Fig. 9, magnified.
,, 10.—*P. subovata*, nov. Right valve, magnified. Natural size, 8 by 6 mm.
,, 11.—*P. subovata*, nov. Left valve. Natural size, $4\frac{1}{2}$ by 3 mm.—Fig. 12, magnified.
,, 13.—*P. subovata*, nov. Left valve. Natural size (of Fig. 15), 6 by $4\frac{1}{2}$ mm.
,, 14.—*P. subovata*, nov. Left valve, showing the interior; magnified. Natural size, $8\frac{1}{3}$ by 6 mm. This is not the magnified view of Fig. 13.
,, 15.—*P. subovata*, nov. Magnified view of Fig. 13.
,, 16.—*Anthracomya Valenciensis*, Etheridge. Left valve. Natural size, 7 by 7 mm.—Fig. 17, magnified.
,, 18.—*Posidonomya concinna*, nov. Fragment. Size of the original shell, 20 by 18 mm.

The enlarged Figures are magnified about three times.

II.—Preliminary Note on some Recently Discovered Extinct Vertebrates from Egypt. (Part II.)

By Chas. W. Andrews, D.Sc., F.G.S., British Museum (Nat. Hist.).

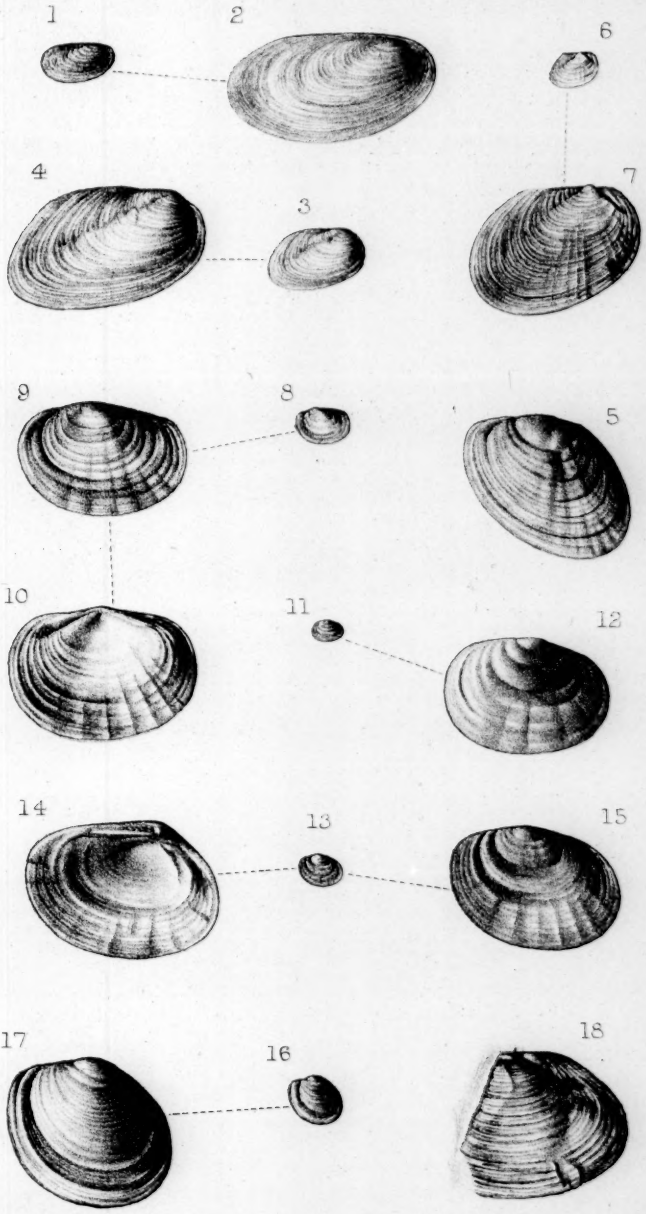
Mammalia (*continued*).

Eotherium ægyptiacum, Owen.

In the lower beds remains of a Sirenian are very common, and several more or less complete skulls associated with some portions of the skeleton were found. The skull in most respects resembles that of *Halitherium*. The snout is strongly deflected and bears a pair of downwardly directed incisor tusks. There are about seven cheek-teeth, resembling in pattern those of *Halitherium*. The roof of the skull between the temporal fossæ is flat. A cast of the brain-case has been made, and in most respects it resembles that described by Owen[1] as the type of *Eotherium ægyptiacum*, from the Mokattam of Cairo. Since this seems to have come from nearly the same horizon as our specimens, I believe that there is the highest probability that they are referable to this same species, in spite of some differences between the shape of the natural cast described by Owen and that artificially made from one of our specimens.

The mandible has a sharply deflected symphysis, which is much thickened below, and it appears that teeth occurred along nearly its whole length. The vertebræ, scapula, and os innominatum are almost exactly as in *Halitherium*. It is, in fact, very remarkable that in a form so old as this (possibly Mid-Eocene, see below) there is no trace of a more generalized structure than in the later *Halitherium*, and we are apparently no nearer the primitive mammalian stock from which the Sirenians sprang.

[1] Quart. Journ. Geol. Soc., vol. xxxi (1875), p. 100.



G.M. Woodward del. et lith. West, Newman imp.

Siberian Anthracomyæ &c.

Zeuglodon Osiris, Dames.[1]

Zeuglodon remains are not uncommon, and we obtained many vertebræ, a fine mandible, and a large part of two skulls, from one of which it will be possible to get a cast of the brain-case. There are two forms, a large and a small, as described by Dames. The smaller is certainly the *Zeuglodon Osiris* of that author, who considers that the differences between the larger and smaller species are merely sexual. Of this there seems to be much doubt, but for the present, until further information is available, it will be convenient to accept this view.

Reptilia.

The reptilian remains collected were very numerous and include some forms of great interest. In many cases the bones were in a wonderfully perfect state of preservation and had been almost completely freed from the matrix. Some of the more important new forms only will be noticed here; these include two species of snakes, three Chelonians, and a Crocodilian.

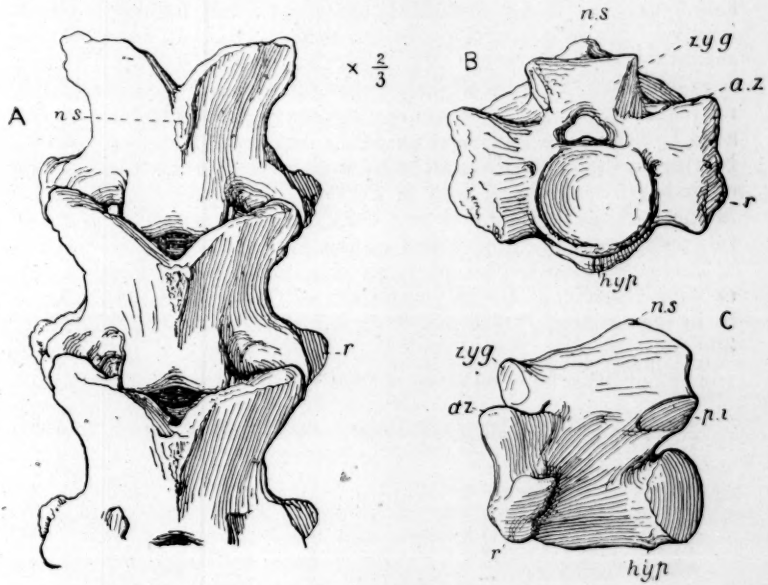


Fig. 1.—Vertebræ of *Gigantophis*. Two-thirds natural size. (A) Three articulated vertebræ from above; (B) vertebra from front; (C) vertebra from side. *a.z.* anterior zygapophysis; *hyp.* hypapophysis; *n.s.* neural spine; *p.z.* posterior zygapophysis; *r.* articular facet for rib; *zyg.* zygosphene.

Ophidia.

The fossil remains of snakes are, as a rule, very rare, but in the lower beds in which our collections were made Ophidian vertebræ

[1] Palaeont. Abhand., neue Folge, Bd. i (1894), p. 189.

were very common. They belong to two types, one an extremely large *Python*-like form, and the other a smaller, though still large snake, the chief characteristic of which is the great height of the neural spines. These two types are briefly described below.

Gigantophis Garstini, gen. et sp. nov. (Fig. 1.)

The large vertebræ of this species occur very commonly in the lower beds associated with remains of *Mœritherium*, Zeuglodonts, and Sirenians. In one case a series of about twenty vertebræ were found in their natural relations to one another and beautifully weathered out of the matrix by the action of sand-drift (Fig. 1A).

The form of these vertebræ (Fig. 1) approaches most nearly to that seen in *Python*, to which genus it seems probable that this species was nearly related. The articular region of a mandible lends support to this view.

In the vertebræ the anterior cup of the centrum is transversely oval, and the corresponding posterior convexity is similar in shape and looks somewhat upwards. The neural spine (*n.s.*) is short and stout, and has a flat truncated extremity; the neural canal is relatively much smaller than in the recent type, but has the same somewhat trilobate form. The articular surfaces of the anterior zygapophyses (*a.z.*) are slightly above the level of the floor of the neural canal. The form of the zygosphene (*zyg.*) and zygantrum are as in *Python*. The transverse processes form massive protuberances, bearing on their outer ends articular surfaces (*r.*) for the ribs, and are of similar form to those seen in *Python*. The hypapophysis (*hyp.*) in most of the vertebræ is small, and consists mainly of a small tuberosity near the hinder end of the centrum.

These vertebræ are all of large size, much larger than in any existing Ophidian. If the proportions of this snake were the same as in the existing *Python sebæ* it probably reached a length of about 30 feet.

The dimensions of one of these vertebræ are as follows:—

	mm.
Greatest height (from top of neural spine to end of hypapophysis) ...	57·5
Greatest width (between the ends of the transverse processes) ...	63
Width of zygosphene	29
Width of articular cup of centrum	22
Height of articular cup of centrum	19
Width of articular ball of centrum	23
Extreme length of centrum	40
Width of neural canal ... ... (approx.)	12

To this form the generic name *Gigantophis*, referring to its large size, may be given, the specific name being *Gigantophis Garstini*, in honour of Sir William Garstin, K.C.M.G., the Under Secretary of State for Public Works in Egypt.

Mœriophis Schweinfurthi, gen. et sp. nov. (Fig. 2.)

Perhaps the commonest fossils in the lower beds are the vertebræ of a large snake, which in the main points agree with those upon which Owen founded the genus *Palæophis*. Owen's specimens are

from the Eocene (Lower and Middle) of Sheppey and Bracklesham, and it is very interesting to find a similar form occurring in the Lower Tertiary deposits of Egypt. Some shells which occur associated with these remains have lately been described by Cossmann[1] from almost the same locality; they are referred by him to the Middle Eocene (Nummulitic), so probably it may turn out that the beds in which *Mœritherium*, *Bradytherium*, and the reptiles described in this paper are found, are somewhat older than stated in Part I, and are in fact Middle Eocene. This question will no doubt be settled by Mr. Beadnell in the section relating to the stratigraphy of the district.

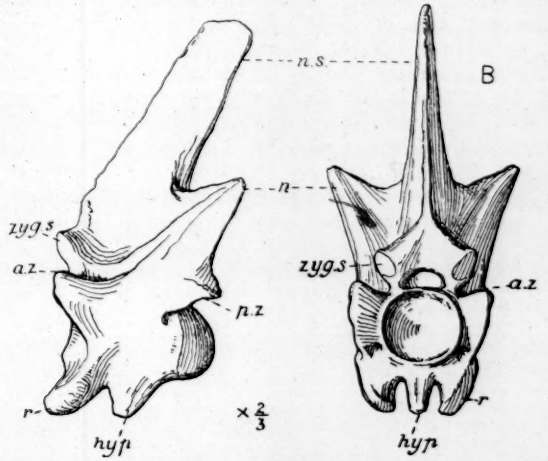


FIG. 2.—Vertebra of *Mœriophis*. Two-thirds natural size. (A) From side; (B) from front. *a.z.* anterior zygapophysis; *hyp.* hypapophysis; *n.* process on back of neural arch; *n.s.* neural spine; *p.z.* posterior zygapophysis; *r.* facet for rib; *zyg.s.* zygosphene.

The chief characteristic of these vertebræ is the great height of the neural spine (Fig. 2, *n.s.*), and with this seems to be correlated the relative narrowness of the centrum in proportion to its length and the ventral and downwardly directed position of the transverse processes (*r.*). All these characters occur to a less degree in *Palæophis*. Another point of similarity is the presence on either side of the posterior part of the neural arch of a large backwardly and upwardly projecting process (Fig. 2, *n.*), from the tip of which a ridge runs downward and forward to the base of the anterior zygapophysis. This process is more developed here than in *Palæophis*, to which, according to Owen, it is almost peculiar, only a trace being found in other Ophidian vertebræ.

The transverse processes project downward below the level of the centrum, and their lower ends may even be slightly bent in

[1] Cossmann: "Additions à la Faune Nummulitique d'Egypte" (Institut Egyptien, Cairo, 1901).

towards the middle line. The hypapophysis (*hyp.*) consists of two processes, one near the middle of the centrum, the other close to its anterior border; the latter, together with the transverse processes, is strongly inclined forward.

The whole form of the vertebra seems to me to indicate that the body was deep and laterally compressed, as in some water-snakes, and to point strongly to the conclusion that this animal was aquatic in its habits. Its association with the remains of Zeuglodonts, Sirenians, and marine turtles seems to support this.

This snake is no doubt a close ally of *Palæophis*, and must be referred to the same family; but the greater height and narrowness of the vertebræ, the more ventral position of the transverse processes, and of their surfaces for articulation with the ribs (*r.*), as well as several points in the structure of the neural arch and its articulations, justify the generic separation of this type. I propose for it the name *Mœriophis*, referring to the locality in which it was found, and its specific name will be *M. Schweinfurthi*, after Dr. G. Schweinfurth, who has done so much to add to our knowledge of Egypt in so many directions, and who seems to have been the first to collect vertebrate remains in the Fayûm.

The dimensions of one of these vertebræ are as follows:—

	mm.
Greatest height (from top of neural spine to end of hypapophysis) ...	85
Greatest width (between ends of transverse processes)	25
Width of zygosphene	19
Width of articular cup of centrum	16
Height of articular cup of centrum	14
Extreme length of centrum	31
Width of neural canal	7

Chelonia.

Chelonian remains are fairly common in the lower beds in which *Mœritherium* and *Gigantophis* occur, and some nearly complete skulls and carapaces were collected. The latter are not in very good condition for the determination of their characters, being, as a rule, traversed in all directions by cracks and coated with gypsum, so that the sutures cannot be clearly made out.

The Chelonians collected include representatives of the three chief groups, viz., the *Athecæ*, *Pleurodira*, and *Cryptodira*.

Psephophorus eocænus, sp. nov.

The *Athecæ* are represented by a humerus and possibly some masses of scutes.

The humerus (Fig. 3) differs widely from that of all land and fresh-water tortoises and of all the marine turtles, except *Sphargis*. In fact, it belongs to the most specialized type of swimming humerus found among the pelagic Chelonia (*parathalassic type* of Wieland, Am. Journ. Sci., ser. IV, vol. ix, 1900, p. 420). Among the forms of Athecate Chelonia of which the humerus is known, the present species (Fig. 3) seems to approach most nearly to *Psephophorus*, the chief points of difference being that the ulnar crest (*a*) is more

prominent and rises farther above the head (*b*), and the form of the proximal portion of the radial process (*c*) is different in several respects. For the present, until further remains are collected, it will be best to refer this form to *Psephophorus*. The specific name will be *P. eocænus*.

Dimensions of Humerus.

Total length	190 mm.
Width of shaft immediately below radial process ...	42 ,,
Width of head	40 ,,

Thalassochelys libyca, sp. nov.

Another Chelonian, represented in the collection by several more or less crushed skulls, is a Cryptodiran with roofed temporal fossæ, apparently closely allied to *Chelone*. In two cases the skulls are greatly crushed from above downward, giving them a quite misleading appearance of being low and flattened, but another specimen, including the back of the skull as far forward as the epipterygoid (columella), is quite uncrushed, and is here referred to.

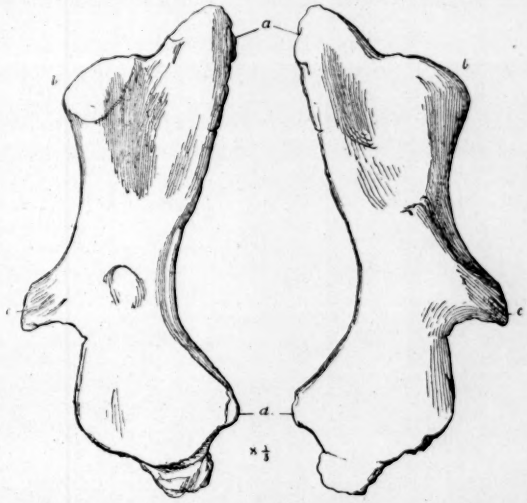


Fig. 3.—Dorsal and ventral views of left humerus of *Psephophorus eocænus*, Andrews. One-fifth natural size. (*a*) Ulnar crest; (*b*) head; (*c*) radial crest; (*d*) entocondyle.

The form of the tympanic ring, which is incomplete posteriorly, resembles that seen in *Chelone*, showing that this species is not a Pleurodiran. The presence of the columella shows that it is not one of the Athecate group, as from the occurrence of the humerus above described seemed not impossible. The roofing of the temporal fossa, as far as can be seen, is the same as in the Chelonidæ, and it may be referred provisionally to that family. The occipital condyle is trilobate, the basi-occipital extending up to the foramen magnum. The basi-sphenoidal platform is much less prominent than in *Chelone*, and there is no deep fossa beneath its hinder border as in that genus.

In this region the skull resembles that of *Thalassochelys* very nearly. There are some differences, however, the most notable of which being the greater length of the quadrate in the fossil. Nevertheless, I prefer at present to refer this species provisionally to *Thalassochelys*, with the specific name *T. libyca*.

Stereogenys Cromeri, gen. et sp. nov.

The most interesting of the Chelonian remains are several more or less complete skulls of a Pleurodiran tortoise, which presents a number of peculiar features. The Pleurodiran nature of this species is shown by (1) the completeness of the quadrate ring for the tympanum; (2) the form of the articular surface of the quadrate.

The temporal fossa is roofed as in *Podocnemis* alone among living Pleurodira. In the Mesozoic *Rhinochelys* also the temporal fossa is roofed in, but in quite a different manner from that occurring in *Podocnemis* and our fossil. So far as I can determine, this species approaches *Podocnemis* more nearly than any other Chelonian, but on the other hand there are some very important differences. The most important of these are found in the structure of the palate (Fig. 4A),

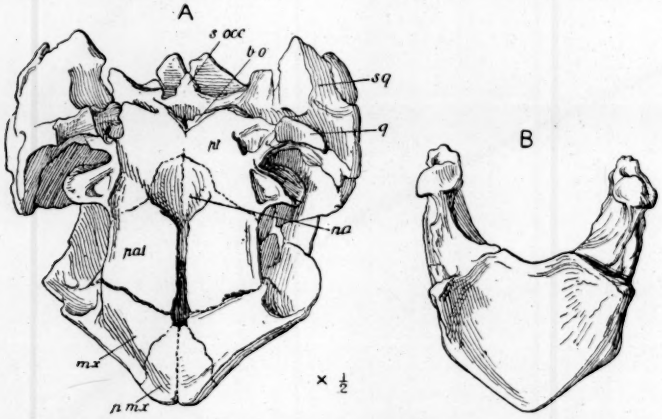


Fig. 4.—Skull and mandible of *Stereogenys Cromeri*. One-half natural size. (A) Palatal surface of skull; (B) upper surface of mandible. The premaxillæ are restored from another specimen. *b.o.* basi-occipital; *mx.* maxilla; *na.* internal nares; *p.mx.* premaxillæ; *pal.* palatines; *pt.* pterygoids; *q.* quadrate; *s.occ.* supra-occipital; *sq.* squamosal.

in which the palatine bones (*pal.*) are much longer than in *Podocnemis*, and are produced inward towards the middle line, where in some specimens they seem to have united in a median suture, in others to have remained separated by a narrow cleft, which in life was no doubt closed by membrane, so that in either case the opening of the internal nares (*na.*) was carried far back to the level of the ectopterygoid wings. This arrangement of the palatines seems to be unique among Chelonia. There is a small anterior vacuity between the hinder ends of the palatal portions of the premaxillæ (*p.mx.*) and the maxillæ (*mx.*). The pterygoids (*pt.*)

are short and broad, and have a very small extension on the palate compared to that seen in *Podocnemis*, and they seem to have been nearly excluded from the middle line by the backward prolongation of the palatines.

Four or five more or less complete skulls of this type were collected, and it will be possible from them to give a detailed account of the cranial characters.

The symphysis of the mandible (Fig. 4B) is very long, and the symphyseal region forms a broad pentagonal plate, the two anterior sides of which form the labial borders, while the two lateral bear the high pointed coronoid processes. The posterior side is slightly concave. The dorsal surface of the symphyseal surface was probably covered by a strong horny plate, which, judging from the large size and anterior position of the coronoid process and the depth of the muscle impressions, must have formed a powerful crushing apparatus. The backward position of the internal nares seems to be correlated with the existence of this arrangement, the union of the palatines extending just far enough backwards to bring the opening behind the level of the symphysis. Probably the anterior part of the palate in front of the narial opening was also covered with a horny plate.

To this new form I propose to apply the generic name *Stereogenys*, the species being called *S. Cromeri*, after the Earl of Cromer, the British Agent and Consul-General at Cairo.

The dimensions of the figured skull and mandible are :—

SKULL.

Extreme length as figured	96 mm.
Extreme width [1]	98 ,,
Width between ends of ectopterygoid wings	65 ,,
Width between outer ends of articular surface of quadrates	74 ,,
Width of articular surface of quadrate	14 ,,

MANDIBLE.

Total length	71 mm.
Length of symphysis	45 ,,
Width at coronoid	55 ,,
Width at articulation for quadrate	64 ,,

Several carapaces and plastra were collected which probably belong to this form. Their Pleurodiran character is shown by the fusion of the lower ends of the pubes and ischia with the plastron. As a rule the mode of preservation is such that it is extremely difficult to make out the position of the sutures, even in specimens otherwise in excellent preservation. In one plastron, however, it seems fairly clear that there were small lateral mesoplastrals and that a large intergular plate was present.

Crocodilia.

Tomistoma africanum, sp. nov.

Remains of Crocodilians are very common in the lower beds in some localities, and in some cases attain a very large size. Vertebræ and scutes, either isolated or in groups, most commonly occur, but occasionally a large part of the skeleton was seen. When

[1] This specimen is somewhat crushed, so that the width is slightly exaggerated.

the material is fully examined it is probable that two or three species will be found. At present it will only be necessary to mention one, to which the finest specimens collected are referable. These include an almost perfect mandible and the anterior portion (about 34 cm. in length) of a snout, with the upper and lower jaws in their natural positions with regard to one another.

In the mandible the symphysis is very long and Gavial-like, but in this region there are only 14 teeth on each side, the total number in each ramus being 19–20. The splenial enters largely into the formation of the symphysis. The first and second teeth are large, the third smaller, the fourth large again, then the remainder somewhat smaller, and of nearly the same size throughout except a few of the hindermost.

There are four premaxillary teeth, of which the second and third are the largest; the fourth is small, and behind it there is a diastema into which the large fourth lower tooth bites. Only the first four of the maxillary teeth are preserved. The teeth are nearly circular in section. The premaxillary region is very slightly flattened and expanded, and the nasal opening is heart-shaped, with the point directed backwards: the relations of the premaxillaries and nasals to it cannot be made out, none of the sutures being visible.

Comparison of this Crocodile with other types shows that without doubt it is referable to the genus *Tomistoma*, the only living species of which occurs in the rivers of the Malay Peninsula, Borneo, and the neighbouring islands, while fossil representatives, or very closely allied types, occur in the Miocene of Malta and Eggenburg.

This species differs from the recent form in the slightly greater expansion of the premaxillary region and the somewhat greater length and slenderness of the articular process of the mandible. Apart from these and some other peculiarities, the difference in the horizon and locality of this form entitles it to specific distinctness; it may be called *Tomistoma africanum*.

The dimensions of the mandible are:—

	cm.
Total length	103
Length of symphysis	49·5
Width of jaw at symphysis	11·2
Width of articular surface for quadrate	6·8
Depth of ramus at symphysis ... ... (approx.)	4·2

In another specimen of the front of the snout the premaxillary expansion is nearly 8 cm. wide, while the somewhat contracted region immediately behind the premaxillary teeth is only 5 cm. in width.

Pisces.

Fish remains were collected in considerable quantity, but have not yet been examined in detail; they seem to be mostly portions of the skeleton of large Siluroids, but remains of a Saw-fish (? *Propristis Schweinfurthi*, Dames) are not uncommon, one complete rostrum being obtained.

III.—On the Circulation of Salt in its Relations to Geology.

By William Ackroyd, F.I.C., F.C.S., Public Analyst for Halifax.

A SEA-BREEZE is salt-laden in varying degree. On a fine dry day it may contain as much as 22 milligrams of salt per cubic metre of air (Armand Gautier, Bull. Soc. Chim., 1899 [iii], 21, 391–392). This invisible salt is washed out of the atmosphere by rains, and finds its way back to the sea.

Salt circulation is more evident in times of storm, when the amount carried on to the land from the sea may be enormous. Thus, during the storm of January 6th and 7th, 1839, newspaper records make it apparent that tons of salt per acre were spread over Lancashire and Yorkshire, which had been brought by the gales from the Irish Sea; right away over the Pennine hills the trees were white with salt.

The phenomenon has been entirely ignored in our physiographic literature, and credit is due to Professor Joly for having made an allowance of 10 per cent. for such transported salt in his calculation of the age of the Earth. I have attempted to give the subject of salt circulation its due importance in a paper read before the Yorkshire Geological and Polytechnic Society, which will duly appear with Addenda in the Society's Proceedings. A preliminary report appeared in the *Chemical News* for June 7th, 1901. In the course of the paper I venture the opinion that 99 per cent. ought to be allowed for cyclic sea-salt in employing soluble river contents as a measure of time; to this Professor Joly replied on June 28th, and my rejoinder in the same journal will be found on August 2nd. I am here concerned with his article in the August number of this Magazine.

On the Origin of the Saltness of Salt Lakes.—Many determinations of chlorine in rain-water are on record, but a fulness of information is decidedly wanting. The chlorine fluctuates widely, and the laws determining the variations have yet to be experimentally worked out. A six months' study of one locality will be found in my paper "On the Origin of Combined Chlorine" (Journ. Chem. Soc., 1901, vol. lxxix, pp. 673 and 674), where records of the fluctuations of chlorine in the rain-gauge and reservoir of Widdop on the Lanc.-Yorks. border are given. It is necessary to say here, a point which will again be referred to, that it is customary among chemists to make chlorine a measure of sodium by calculating the chlorine in rainfall into sodium chloride. Employing this convention, Bellucci calculates that 37·8 lbs. of common salt per acre is deposited every year at Perugia, some 75 miles from the sea-coast, and I may add that I find in the Pennine hills the deposit calculates out to 172 lbs. per acre per year. Such facts, taken in conjunction with observations like Gautier's, make it probable that wherever sea-winds reach to carry moisture there the falling rains bring down chlorides, and the general disposition of iso-chlors proves this. It is justifiable, then, to suppose that an inland lake may owe much of its salt to this source. I have shown by calculations that the Pennine reservoir already referred to with

a capacity of 640·5 millions of gallons has in it some 55 tons of salt, and as the water is being continually drawn off for municipal use, and as continually being replenished by rains falling on a saltless area of Millstone Grit, it follows that its chlorides must be derived from the sea. The available data show further that if it had no outlet and the inflow were balanced by the effects of evaporation it would become salter than the Dead Sea in a period of time less than one-seventh of that usually assigned to the Pleistocene Age. The mind naturally turns from such considerations to a case like that of the Dead Sea, for it is little further removed from the Mediterranean than Widdop is from the Irish Sea; there is a rainfall in Palestine higher than that of the Pennine hills, and in the past there has been an intensity of meteorological conditions of which we at the present day can form but an inadequate conception (Tristram, "The Land of Israel," p. 320). All the conditions are present, but what of the results? The various points of similarity and of dissimilarity are in favour of such a hypothesis; it will be convenient to deal with them after the next paragraph.

Indiscriminate comparisons of salt-lake analyses lead to confusion. This is illustrated by Professor Joly's remarks on p. 346 of this Magazine for August. A principle is here overlooked which may be thus briefly stated:—Where a solution of mixed salts, among them being magnesium chloride and sodium chloride, undergoes concentration, as the more soluble magnesium chloride increases in amount the common salt is precipitated. The only reference on which I can lay my hands at the moment is to the work of Precht and Wittjen in 1881 (Journ. Chem. Soc., November, 1881, p. 978), who show that a 20 per cent. solution of magnesium chloride at 20° C. dissolves only 5·1 per cent. of potassium chloride and 5·8 per cent. of sodium chloride. Now in this strong light let us examine the waters of the Elton Lake of the Kirghis Steppe as they vary with the season:—

	In Spring (Göbel).	In Summer (Erdmann).	In Autumn (Rose).
Sodium chloride, $NaCl$	13·1	7·4	3·8
Magnesium chloride, $MgCl_2$	10·5	16·3	19·7
Potassium chloride, KCl	0·2	—	0·2
Calcium chloride, $CaCl_2$	—	—	—
Potassium sulphate, K_2SO_4	—	0·04	—
Magnesium sulphate, $MgSO_4$ ...	1·6	2·20	5·3
Water	74·4	73·50	70·8
	99·8	99·44	99·8

On Professor Joly's line of argument the first and last analyses ought not to belong to the same lake, but they are beautifully in keeping with the principle I have enunciated. Nor does it at all seem strange that in the case of the Great Salt Lake, where there is so little magnesium chloride there should be so much common salt.

To return now to the Dead Sea. It will be at once recognized that the large percentage of magnesium chloride present, arising from ages of concentration, is favourable to precipitation of common salt, which in the southern parts of the lake forms quite a paste (Tristram). The ratio of chlorine to bromine in the surface waters of the Dead Sea and of the Mediterranean are nearly alike (100 : 2·1), and the only divergence one looks for is in the increase of the bromine figure for the Dead Sea as its sodium chloride is precipitated, and this one finds to be the case. It is also to be noted here that all attempts to find traces of bromine in the springs and rivers of Palestine have hitherto failed (Watts' Dictionary of Chemistry, vol. v, p. 183). All these points are compatible with the Dead Sea having derived the greater part of its salts from the Mediterranean. As one recognizes, however, that solvent denudation must play an important part in adding to the soluble contents of inland lakes, it is to its extensive limestone gathering-ground that the Dead Sea must owe its calcareous character, and the contrast in this respect with the Mediterranean is increased by the latter possessing and the former being without a lime-secreting fauna.

On the Proportion of Chlorides supplied by Solvent Denudation.—It was of interest and of importance to know approximately what in a river water was due to solvent denudation and what to atmospheric transportation. To find the proportion of chlorides due to solvent denudation the following line of reasoning suggested itself to me. A sample of Malham Cove water in Craven had a hardness of 10°, i.e. it contained 10 grains of calcium carbonate per gallon or its equivalent of dolomitic compound. Analysis showed the limestone to have in it ·01 per cent. of combined chlorine. The 10 grains therefore contained ·001 grain of chlorine. Now the whole gallon of water gave ·7 grain of chlorine, whence it follows that only a fifth of 1 per cent. of all the combined chlorine in the water was due to solvent denudation, or of the load of salt carried to the sea approximately 99·8 per cent. was sea-salt. Professor Joly, in his criticism in the *Chemical News*, does not appreciate this result; in the Geological Magazine he ignores it altogether. It is capable of wide application. Thus, in some 40 full analyses of limestones and dolomites published by the United States Geological Survey (Bull., 148, pp. 254–274), 31 samples show no trace of chlorine, 2 only traces, and 9 samples from ·01 up to ·14 per cent. The average quantity of chlorine in the last 9 samples is ·06 per cent., and in the whole 40 samples ·01 per cent. Limestone is one of the most soluble of all rocks, and will probably furnish the largest share of chlorine to the rivers, and these figures demonstrate that so far as the North American continent is concerned its limestones are not likely to supply any greater proportion of this element than the limestones of Yorkshire. Reference to other facts confirm this view of things. Before proceeding farther let me give the atomic proportions of sodium and chlorine in some of the bodies we have to deal with, premising for the benefit of the non-chemical reader that

a molecule of common salt or sodium chloride contains two atoms, one of chlorine and one of sodium.

		Atomic Proportions. Sodium.		Chlorine.
1.	In common salt	1	:	1
2.	In the solids dissolved in sea-water	1	:	1·17
3.	In Pierre's rain	1	:	1·3
4.	In the solids dissolved in average river-water (from Sir J. Murray's data)	1	:	0·345
5.	In the older crust of the earth (from Professor F. W. Clarke's data)	1	:	0·0024

Compare 4 and 5. In the earth's crust there is only one atom of chlorine to 417 atoms of sodium, while in river-water to each atom of chlorine we have three atoms of sodium. Therefore average river-water contains a proportion of over 140 times more chlorine atoms than the earth's crust could supply it with. Where does it get them from if transported sea-salt does not enter into the composition of the so-called average river-water? This difficulty presented itself in another form to the Rev. Osmond Fisher when he asked: "Whence came the chlorine? The amount of 0·01 per cent. stated to occur in crystalline rocks seems insufficient" (Geol. Mag., March, 1900, p. 129).

The Age of the Earth.—Now come we to the knotty question of the bearing of the foregoing facts on the rate of solvent denudation used as a measure of time. Here I have to point out the important fact that in estimating the numerator *all the sodium of the sea has been calculated from sodium chloride.* This involves the tacit assumption that all the sodium going into the sea throughout the ages has either gone there allied with chlorine or has finally taken the form of sodium chloride. In either case the chemist's convention of taking chlorine as a measure of sodium in rain- and river-water is serviceable, and cannot involve more final error in connection with this problem than that indicated by the ratio of these elements in sea-water. Our estimate of 99 per cent. for cyclic sea-salt therefore still stands, and, being applied to Professor Joly's calculation, brings the age of the Earth to over 8,000 millions of years; and even if we were inclined to be prodigal in this respect and only deduct so little as 80 per cent. for cyclic salt the age of the Earth would still come to over 400 millions of years!

I will not go further into this matter here than to point out that Professor Joly's grounds for making an allowance of 10 per cent. for cyclic sea-salt is not convincing reading. We are invited to contrast the chlorine content of average *river*-water, put at ·3 part per 100,000, with the chlorine content of *rainfall* at Ootacamund in India, which is given as ·04 part per 100,000. It would have been more conducive to progress in this discussion if relevant particulars had been given of the Ootacamund region. Knowing as I do that chlorine content and amount of rainfall bear an inverse relation to each other, and that in some parts of India the rainfall is prodigious in amount, any isolated fact concerning the chlorine content of a sample of rain does not add to our enlightenment, because for

anything we know to the contrary the nearest river-water may give no higher figure; the Mahanuddy, emptying itself into the Bay of Bengal, has only a chlorine content of ·17 per 100,000 after passing over 440 miles of its course (Nicholson, Journ. Chem. Soc., 1873, p. 229).

IV.—The Periodicity of Earthquakes.

By R. D. Oldham, Superintendent of the Geological Survey of India.

MANY are the attempts that have been made to discern some law in the occurrence of earthquakes, and to trace the influence of the sun, the moon, or even of the planets as a cause, if partial, of their origin. Many patient investigators have discovered, or thought they have discovered, periods of fluctuating seismic activity, varying in length from semi-diurnal to annual or even longer, but so conflicting have been their conclusions that little weight can be, or has been, attached to the results of their calculations; and one of the most industrious of all these investigators, the Commandante de Montessus de Ballore, has declared his conviction that no periodicity can be detected, and that the causes of earthquakes are purely terrestrial and in no way affected by any celestial body. Yet, in spite of this, the attempts and the calculations go on, and one of the most recent of these is a discussion by Herr M. Becke of some three hundred earthquakes recorded in the region round Karlsbad between 24th October and 25th November, 1897.[1]

Tabulating these, according to the hour of occurrence, he finds that there are two well-defined maxima at about three hours on either side of midnight, while the minimum is at midday with a minor one at midnight. He rightly observes that if this be due to the influence of the sun a similar but much more marked relation should be observed in the case of the moon, and after dividing each lunar day into twenty-four hours and tabulating the earthquakes according to this lunar time he finds that the curve of frequency so obtained does not correspond to that deduced from solar times. From this he concludes that the apparent maxima do not represent real maxima of occurrence of earthquakes, but merely maxima of record, due to the fact that slight earthquakes, which would be noticed and recorded in the morning and evening hours of repose, would be overlooked in the active prosecution of daily avocations, or in the slumber of the night. To this the obvious objection may be raised, that persons who are asleep by midnight are not likely to be awake at 3 o'clock in the morning.

Apart from this, there seems to be a more serious flaw in the argument. Herr Becke appears to have expected that the curve of frequency by lunar time should show maxima at about three hours on either side of the time of lower meridian passage of the moon. This again depends on the assumption, tacitly made by every calculator with whose work I am acquainted, that the frequency may be expected to be a function of the hour angle.

[1] M. Becke, "Bericht über das Graslitzer Erdbeben, 24 October bis 25 November, 1897": Sitzber. k. Akad. Wiss. Wien, 1898, cvii, Abth. 1, pp. 789–959.

This would be true if the frequency were such a function of the zenith distance of the sun or moon that the one might be expected to increase or decrease continuously with the other. This is, however, by no means necessarily, or even probably, the case, for if the attraction of the sun or the moon have any effect it is probably through the strains set up by the tide-producing forces.

Now these have three separate maxima distributed in two points and three circles: at the extremities of the diameter pointing to the sun or moon, as the case may be, the upward vertical tide-producing force is at its maximum; the maximum of the downward tide-producing force lies along the great circle at right angles to this diameter; while the maximum horizontal tide-producing force lies along the small circles half-way between. If, then, external attraction is in any way the cause of earthquakes, we may look for the frequency to have some relation to the times of passage of one or other of these points or circles over the place where the earthquakes originated. I am at present engaged in a discussion of the records of the after-shocks of the great earthquake of 1897, with a view to seeing whether any such relation can be traced; the discussion is not yet far enough advanced to have yielded any results, and the matter would not have been referred to but that in the paper quoted above the records are tabulated in a form which makes it possible, without lengthy calculation, to roughly test the hypothesis that the frequency of earthquakes is influenced by the tide-producing force generated in the earth by the sun and moon.

The three hundred earthquakes, recorded during a period of little over a lunar month, are classified, according to time of occurrences, and also with regard to the phases of the moon, as to whether the earthquake occurred nearer to the syzygies or the quadratures. In the table printed below the figure opposite to 0 is the total recorded

	Solar Times.			Lunar Times.		
Hour.	Syz.	Quad.	Total.	Syz.	Quad.	Total.
0	7	13	20	9	6	15
2	14	31	45	4	9	13
4	16	17	33	9	13	22
6	16	16	32	13	11	24
8	4	14	18	12	17	29
10	4	4	8	18	12	30
12	3	8	11	8	21	29
14	9	9	18	14	15	29
16	15	6	21	13	14	27
18	18	12	30	17	11	28
20	19	17	36	12	20	32
22	14	13	27	10	11	21
24	7	13	20	9	6	15

in the hour preceding and that following the lower culmination, that opposite 2 being the total recorded between one and three hours after the lower culmination, and so on.

Taking the solar times first, the sun's declination was south, and increasing slowly throughout the period of the record; the mean value may be taken as 16° south and the mean latitude of the origins of the earthquakes 50° north. Hence the sun was always more than 60° from the zenith at its upper culmination, and the circle of maximum horizontal tide-producing force nearest the sun never reached the place of origin of the earthquakes. That furthest away from the sun did, however, cross this, and an easy calculation shows that, for a latitude of 50° north and a declination of 11° south, the times of crossing would be about $2\frac{1}{2}$ hours before and after midnight. The observed maxima accord very fairly well with the times of passage of the circle of maximum horizontal tide-producing force due to the attraction of the sun.

Turning to the moon, the problem is not so simple, for, instead of preserving a fairly constant declination like the sun, the moon ranged from its extreme northerly to its extreme southerly declination. Luckily, however, the syzygies happened to nearly coincide with the extreme declinations, while the quadratures were as close to the times when the moon crossed the equator. Now when on the equator the circles of maximum horizontal tide-producing force would never reach 50° north latitude, and only when the declination increased to 5° would one of them touch it, at the upper or lower culmination as the case might be. Moreover, as the rate of change has probably more effect than the amount of the force, and as this rate of change would be small in the case of such tangential passage of the circle, we might expect the effect to be small, but so far as it goes to show a slight tendency to maxima coincident with the upper and lower culmination.

As a matter of fact, there is no marked sign of periodicity except a small increase in frequency about the upper and a decrease at the lower culmination which may be accidental.

At the syzygies the moon was near its maximum declination, and for a declination of 25° one circle of maximum horizontal tide-producing force would never touch latitude 50° north, while the other would cross the place of origin at five hours before and after the upper or lower culmination, according as the moon's declination was north or south. As the declination decreased this interval would decrease, but would not fall much below three hours before the moon passed the half-way point between the syzygies and quadratures; and as the declination was north during half the period of record and south during the other half, the result is that we should expect to find no well-defined maxima, but a greater number of earthquakes occurring more than three hours from the culminations and fewer occurring within three hours of them. Such is practically the case, and the accordance is as close as could reasonably be expected from so limited a record.

So far, then, from the tabulated results showing no indication of any influence of the sun and the moon, they distinctly support the hypothesis of a maximum frequency at the time of passage of the circle of maximum horizontal tide-producing force. They are far

from sufficient to establish this hypothesis, but as it has been clearly shown that there is no relation between hours and frequency which holds good for all times and places, it is in this direction that investigation must now be turned before we can finally say that the attraction of the sun and moon has or has not an effect on the occurrence of earthquakes. If it be found that there is no diurnal periodicity corresponding to the tidal forces produced by them, it may safely be said that any periodicity of longer period, which may appear to correspond with the movements of these or any other heavenly bodies, cannot be due to their attraction; and, unless we assume a hyperphysical or astrological influence of the sun and planets, we must finally conclude that earthquakes are as purely terrestrial in their cause as in their effect.

NOTICES OF MEMOIRS.

I.—British Association for the Advancement of Science. Glasgow, September 12th, 1901.

Address to the Geological Section, by John Horne, F.R.S. L. & E., F.G.S., President of the Section.

Recent Advances in Scottish Geology.

THE return of the British Association after the lapse of a quarter of a century to the second city of the empire, which since 1876 has undergone remarkable development, due in no small measure to the mineral wealth of the surrounding district, suggests the question, Has Scottish geology made important advances during this interval of time? Have we now more definite knowledge of the geological systems represented in Scotland, of their structural relations, of the principles of mountain-building, of the zonal distribution of organic remains, of the volcanic, plutonic, and metamorphic rocks so largely developed within its borders? It is true that many problems still await solution, but anyone acquainted with the history of geological research must answer these questions without hesitation in the affirmative. In the three great divisions of geological investigation — in stratigraphical geology, in palæontology, in petrology—the progress has indeed been remarkable.

. . . . . .

The belt of Archæan gneisses and schists, which may be said to form the foundation-stones of Scotland, have been mapped in great detail by the Geological Survey since 1883 along the western part of the mainland in the counties of Sutherland and Ross. In that region they occupy a well-defined position, being demonstrably older than the great sedimentary formation of Torridon Sandstone and overlying Cambrian strata. The mapping of this belt by the Survey staff and the detailed study of the rocks both in the field and with the microscope by Mr. Teall have revealed the complexity of the structural relations of these crystalline masses, and have likewise thrown considerable light on their history. These researches indicate that, in the North-West Highlands, the Lewisian (Archæan) gneiss may be resolved into (1) a fundamental complex, composed mainly of gneisses that have affinities with plutonic igneous products, and to a limited extent of crystalline schists which may without doubt be regarded as of sedimentary origin; (2) a great series of

igneous rocks intrusive in the fundamental complex in the form of dykes and sills.[1]

The rocks of the fundamental complex which have affinities with plutonic igneous products occupy the greater part of the tract between Cape Wrath and Skye. Mr. Teall has shown that they are essentially composed of minerals that enter into the composition of peridotites, gabbros, diorites, and granites ; as, for example, olivine, hypersthene, augite (including diallage), hornblende, biotite, plagioclase, orthoclase, microcline, and quartz. In 1894 he advanced a classification of these rocks, based mainly on their mineralogical composition and partly on their structure, which has the great merit of being clear, comprehensive, and independent of theoretical views as to the history of the rock-masses. Stated broadly, the principle forming the basis of classification of three of the groups is the nature of the dominant ferro-magnesian constituent, viz., pyroxene, hornblende, or biotite, while the members of the fourth group are composed of ferro-magnesian minerals without felspar or quartz.[2] The detailed mapping of the region has shown that these rock-groups have a more or less definite geographical distribution. Hence the belt of Lewisian gneiss has been divided into three districts, the first extending from Cape Wrath to Loch Laxford, the second from near Scourie to beyond Lochinver, and the third from Gruinard Bay to the island of Raasay. In the central area (Scourie to Lochinver) pyroxene gneisses and ultrabasic rocks (pyroxenites and hornblendites) are specially developed, while the granular hornblende rocks (hornblende gneiss proper) and the biotite gneisses are characteristic of the northern and southern tracts. These are the facts, whatever theory be adopted to explain them.

In those areas where the original structures of the Lewisian gneiss have not been effaced by later mechanical stresses it is possible to trace knots, bands, and lenticles of unfoliated, ultrabasic, and basic rocks, to note the imperfect separation of the ferro-magnesian from the quartzo-felspathic constituents, to observe the gradual development of mineral banding and the net-like ramification of acid veins in the massive gneisses. Many of these rocks cannot be appropriately described as gneiss. Indeed, Mr. Teall has called attention to the close analogy between these structures and those of plutonic masses of younger date.

In the Report on Survey Work in the North-West Highlands published in 1888, the parallel banding, or first foliation, as it was then termed, of these original gneisses was ascribed to mechanical movement.[3] But the paper on "Banded Structure of Tertiary Gabbros in Skye," by Sir A. Geikie and Mr. Teall,[4] throws fresh light on this question. In that region the gabbro displays the alternation of acid and basic folia, the crumpling and folding of the bands like the massive gneisses of the Lewisian complex. Obviously in the Skye gabbro the structures cannot be due to subsequent earth-movements and deformation. The authors maintain that they are original structures of the molten magma, and, consequently, that much of the mineral banding of the Lewisian gneisses, as distinguished from foliation, may be due to the conditions under which the igneous magma was erupted and consolidated. Whatever theory be adopted to explain the original mineral banding of the Lewisian gneisses,

[1] Report on the Recent Work of the Geological Survey in the North-West Highlands of Scotland, based on the field-notes and maps of Messrs. B. N. Peach, J. Horne, W. Gunn, C. T. Clough, L. W. Hinxman, and H. M. Cadell: Quart. Journ. Geol. Soc., vol. xliv, p. 387; and Ann. Rep. Geol. Surv., 1894, p. 280, and 1895, p. 17.

[2] Ann. Rep. Geol. Surv., 1894, p. 280.

[3] Quart. Journ. Geol. Soc., vol. xliv, p. 400.

[4] Ibid., vol. L, p. 645.

it is certain that they possessed this banding, and were thrown into gentle folds before the uprise of the later intrusive dykes.

The crystalline schists that have affinities with rocks of sedimentary origin occupy limited areas north of Loch Maree and near Gairloch. The prominent members of this series are quartz schists, mica schists, graphitic schists, limestones and dolomites with tremolite, garnet and epidote.[1] They are there associated with a massive sill of epidiorite and hornblende schist. The relations which these altered sediments bear to the gneisses that have affinities with plutonic igneous products have not been satisfactorily determined. But the detailed mapping has proved that north of Loch Maree they rest on a platform of Lewisian gneiss, and are visibly overlain by gneiss with basic dykes (Meall Riabhach), and that both the gneiss complex and altered sediments have been affected by a common system of folds. In the field, bands of mylonized rock have been traced near the base of the overlying cake of gneiss, and the microscopic examination of the latter by Mr. Teall has revealed cataclastic structures due to dynamic movement. It is obvious, therefore, that, whatever may have been the original relations of the altered sediments to the gneiss complex, these have been obscured by subsequent earth-stresses.

The great series of later igneous rocks which pierce the fundamental complex in the form of dykes and sills is one of the remarkable features in the history of the Lewisian gneiss. In 1895 Mr. Teall advanced a classification of them,[2] but his recent researches show that they are of a much more varied character. For our present purpose we may omit the dykes of peculiar composition and refer to the dominant types. These comprise : (1) ultrabasic rocks (peridotite), (2) basic (dolerite and epidiorite, and (3) acid (granite and pegmatite). The evidence in the field points to the conclusion that the ultrabasic rocks cut the basic, and that the granite dykes were intruded into the gneisses after the eruption of the basic dykes. The greater number of these dykes consists of basic materials. It is important to note that the basic rocks best preserve their normal dyke-like features in the central tract between Scourie and Lochinver, where they traverse the pyroxene gneisses. But southwards and northwards of that tract, in districts where they have been subjected to great dynamic movement, they appear as bands of hornblende schist, which are difficult to separate from the fundamental complex. The acid intrusions are largely developed in the northern tract between Laxford and Durness ; indeed, at certain localities in that region the massive and foliated granite and pegmatite are as conspicuous as the biotite gneisses and hornblende gneisses with which they are associated.

After the eruption of the various intrusive dykes the whole area was subjected to enormous terrestrial stresses, which profoundly affected the fundamental complex and the dykes which traverse it. These lines of movement traverse the Lewisian plateau in various directions, producing planes of disruption, molecular rearrangement of the minerals, and the development of foliation. It seems to be a general law that the new planes of foliation both in the gneiss and dykes are more or less parallel with the planes of movement or disruption. If the latter be vertical or nearly horizontal the inclination of the foliation planes is found to vary accordingly.

Close to the well-defined disruption planes, like those between Scourie and Kylesku, the gneiss loses its low angle, and is thrown into sharp folds, the axes of which are parallel with the planes of movement. The folia

[1] Ann. Rep. Geol. Surv., 1895, p. 17.
[2] Ibid., p. 18.

are attenuated, there is a molecular rearrangement of the minerals, and the resultant rock is a granulitic gneiss. Indeed, the evidence in the field, which has been confirmed by the microscopic examination of the rocks by Mr. Teall, seems to show that granulitic biotite and hornblende gneisses are characteristic of the zones of secondary shear. A further result of these earth-stresses is the plication of the original gneisses in sharp folds, trending N.W. and S.E. and E. and W., and the partial or complete recrystallization of the rocks along the old planes of mineral banding.

In like manner, when the basic dykes are obliquely traversed by lines of disruption, they are deflected, attenuated, and within the shear zones appear frequently as phacoidal masses amid the reconstructed gneiss. These phenomena are accompanied by the recrystallization of the rock and its metamorphosis into hornblende schist. Similar results are observable when the lines of movement are parallel with the course of the dykes. All the stages of change from the massive to the schistose rock can be traced—the replacement of the pyroxene by hornblende, the conversion of the felspar, and the development of granulitic structure with foliation. Here we have an example of the phenomena developed on a larger scale by the Post-Cambrian movements, viz., the production of common planes of schistosity in rocks separated by a vast interval of time, quite irrespective of their original relations. For both gneiss and dykes have common planes of foliation, resulting from earth-stresses in Pre-Torridonian time.

It is important to note also that linear foliation is developed in the basic dykes where there has been differential movement of the constituents in folded areas. In the case of the anticline mapped by Mr. Clough, near Poolewe in Ross-shire, he has shown that the linear foliation is parallel with the pitch of the folds. All these phenomena tend to confirm the conclusions arrived at by Mr. Teall, and published in his well-known paper "On the Metamorphosis of Dolerite into Hornblende Schist." [1]

The ultrabasic and acid rocks likewise occur in the schistose form, for the peridotites pass into talcose schists and the granite becomes gneissose.

In connection with the development of schistosity in these later intrusive rocks it is interesting to observe that where the basic dykes merge completely into hornblende schist, and seem to become an integral part of the fundamental complex, biotite gneisses and granular hornblende gneisses prevail. Whatever be the explanation the relationship is suggestive.

The unconformability between the Lewisian gneiss and the overlying Torridon Sandstone, which was noted by Macculloch and confirmed by later observers, must represent a vast lapse of time. When tracing this base-line southwards through the counties of Sutherland and Ross, striking evidence was obtained by the Geological Survey of the denudation of that old land surface. In the mountainous region between Loch Maree and Loch Broom it has been carved into a series of deep narrow valleys with mountains rising to a height of 2,000 feet. In that region it is possible to trace the orientation of that buried mountain chain and the direction of some of the old river courses. This remnant of Archæan topography must be regarded as one of the remarkable features of that interesting region.

In 1893 the various divisions of the Torridon Sandstone, as developed between Cape Wrath and Skye, were tabulated by the Geological Survey, and may here be briefly summarized. They form three groups : a lower, composed of epidotic grits and conglomerates, dark and grey shales

[1] Quart. Journ. Geol. Soc., vol. xli, p. 133.

with calcareous bands, red sandstones, and grits ; a middle, consisting of a great succession of false-bedded grits and sandstones ; an upper, comprising chocolate-coloured sandstone, micaceous flags with dark shales and calcareous bands. The total thickness of this great pile of sedimentary deposits must be upwards of 10,000 feet, and if Mr. Clough's estimate of the development of the lower group in Skye be correct, this amount must be considerably increased. Of special interest is the evidence bearing on the stratigraphical variation of the Torridon Sandstone when traced southwards across the counties of Sutherland and Ross. The lower group is not represented in the northern area, but southwards, in Ross-shire, it appears, and between Loch Maree and Sleat varies from 500 to several thousand feet in thickness. These divisions of the Torridon Sandstone are of importance in view of the correlation of certain sediments in Islay with the middle and lower Torridonian groups which there rest unconformably on a platform of Lewisian gneiss.

In continuation of the researches of Dr. Hicks, published in his paper "On Pre-Cambrian Rocks occurring as Fragments in the Cambrian Conglomerates in Britain,"[1] Mr. Teall has specially investigated the pebbles found in the Torridon Sandstone. The local basement breccias of that formation have doubtless been derived from the platform of Lewisian gneiss on which they rest, but the pebbles found in the coarse arkose tell a different story.[2] He has found that they comprise quartzites showing contact alteration, black and yellow cherts, jaspers with spherulitic structures which indicate that they have been formed by the silicification of liparites of the 'Lea-rock' type and spherulitic felsites that bear a striking resemblance to those of Uriconian age in Shropshire. These interesting relics have been derived from formations which do not now occur anywhere in the western part of the counties of Sutherland and Ross, and they furnish impressive testimony of the denudation of the Archæan plateau in Pre-Torridonian time.

These Torridonian sediments, like the sandstones of younger date, contain lines of heavy minerals, such as magnetite, ilmenite, zircon, and rutile.[3] The dominant felspar of the arkose group is microcline, that of the basal group oligoclase. In the calcareous sediments of the upper and lower groups fossils might naturally be expected, but the search so far has not been very successful. Certain phosphatic nodules have been found in dark micaceous shales of the upper group which have been examined by Mr. Teall. From their chemical composition these nodules might be regarded as of organic origin ; but he has found that they contain spherical cells with brown-coloured fibres, which appear to be débris of organisms.[4]

Early in last century the Torridonian deposits were referred by Macculloch[5] and Hay Cunningham[6] to the 'Primary Red Sandstone,' and by Murchison,[7] Sedgwick, and Hugh Miller to the Old Red Sandstone. The structural relations of the Torridon Sandstone to the overlying series of quartzites and limestones were first clearly shown by Professor Nicol,[8] who traced the unconformability that separates them for 100 miles across the counties of Sutherland and Ross. When Salter pointed out the Silurian facies of the fossils found in the Durness Limestone by Mr. Charles Peach, the Torridonian formation was correlated with the Cambrian rocks

[1] Geol. Mag., Dec. III, Vol. VII (1890), p. 516.
[2] Ann. Rep. Geol. Surv., 1895, p. 20.
[3] Ann. Rep. Geol. Surv., 1893, p. 263.
[4] Ibid., 1899, p. 185.
[5] Trans. Geol. Soc., ser. I, vol. ii, p. 450 ; "The Western Isles of Scotland," vol. ii, p. 89.
[6] Trans. Highland and Agricultural Society of Scotland, vol. xiii (1839).
[7] Trans. Geol. Soc., ser. II, vol. iii, p. 155.
[8] Quart. Journ. Geol. Soc., vol. xiii, p. 17.

of Wales by Murchison.[1] The discovery of the *Olenellus* fauna, indicating the lowest division of the Cambrian system, in the quartzite-limestone series by the Geological Survey in 1891[2] demonstrated the Pre-Cambrian age of the Torridon Sandstone. In view of that discovery, which proves the great antiquity of the Torridonian sediments, it is impossible to climb those picturesque mountains in Assynt or Applecross without being impressed with the unaltered character of these deposits. Yet it can be shown that under the influence of Post-Cambrian movements they approach the type of crystalline schists.

Before proceeding to the consideration of the Durness series of quartzites and limestones and their relations to the Eastern Schists, brief reference must be made to the controversy between Murchison and Nicol regarding the sequence of the strata.

The detailed mapping of the belt between Eriboll and Skye by the Geological Survey has completely confirmed Nicol's conclusions (1) that the limestone is the highest member of the Durness series; (2) that the so-called 'Upper Quartzite' and 'Upper Limestone' of Murchison's sections are merely the repetition of the lower quartzite and limestone due to faults or folds; (3) that there is no conformable sequence from the quartzites and limestones into the overlying schists and gneiss; (4) that the line of junction is a line of fault indicated by proofs of fracture and contortion of the strata. It is true that in the course of his investigations Nicol's views underwent a process of evolution, and that even in the form in which he ultimately presented them he did not grasp the whole truth. We now know that he was in error when he regarded portions of the Archæan gneiss, occurring in the displaced masses, as igneous rocks intruded during the earth-movements, and that he failed to realize the evidence bearing on dynamic metamorphism resulting from these movements. But I do not doubt that the verdict of the impartial historian will be that Nicol displayed the qualities of a great stratigraphist in grappling with the tectonics of one of the most complicated mountain chains in Europe.

The period now under review embraces the reopening of that controversy in 1878 by Dr. Hicks, and its close in 1884 after the publication of the "Report on the Geology of the North-West of Sutherland" by the Geological Survey.[3] The Survey work has confirmed Professor Bonney's identification of the Lewisian gneiss and Torridon Sandstone in Glen Logan, Kinlochewe,[4] brought into that position by a reversed fault; and Dr. Callaway's conclusions regarding overthrust faulting at Loch Broom, in Assynt and in Glencoul.[5] Special reference must be made to the remarkable series of papers by Professor Lapworth on "The Secret of the Highlands," in which he demonstrated the accuracy of Nicol's main conclusions, and pointed out that the stratigraphical phenomena are but the counterpart of those in the Alps as described by Heim.[6] His researches, moreover, led him to a departure from Professor Nicol's views regarding the age, composition, and mode of formation of the Eastern Schists, for in the paper which he communicated to the Geologists' Association in 1884 he announced that their present foliated and mineralogical characters had been developed by the crust-movements which operated in that region since the time of the Durness quartzites and limestones.[7] Allusion must

[1] Ibid., vol. xv, p. 353.
[2] Ibid., vol. xlviii, p. 227.
[3] *Nature*, vol. xxxi, p. 29, November, 1884.
[4] Quart. Journ. Geol. Soc., vol. xxxvi, p. 93.
[5] Ibid., vol. xxxix, p. 416.
[6] Geol. Mag., Dec. II, Vol. X (1883), pp. 120, 193, 337.
[7] Proc. Geol. Assoc., vol. viii, p. 438; Geol. Mag., Dec. III, Vol. II (1885), p. 97.

be made also to his great paper "On the Discovery of the *Olenellus* Fauna in the Lower Cambrian Rocks of Britain," in which he not only chronicled the finding of this fauna at the top of the basal quartzite in Shropshire, but suggested the correlation of the Durness quartzites and limestones with the Cambrian rocks elsewhere.[1] That suggestion was strikingly confirmed within three years afterwards by the discovery of the *Olenellus* fauna in Ross-shire.

The detailed mapping of the belt of Cambrian strata has proved the striking uniformity of the rock sequence. There is little variation in the lithological characters or thicknesses of the various zones. Basal quartzites, pipe-rock, Fucoid-beds, Serpulite (*Salterella*) grit, limestone, and dolomite form the invariable sequence, for a distance of a hundred miles, to the west of the line of earth-movements. This feature is also characteristic of the fossiliferous zones, for the sub-zones of the pipe-rock, the *Olenellus* fauna in the Fucoid-beds, and the *Salterella* limestone have been traced from Eriboll to Skye. Owing to the interruption of the sequence by reversed faults or thrusts, the higher fossiliferous limestone zones are never met with between Eriboll and Kishorn, but they occur in Skye, where they were first detected by Sir A. Geikie.[2]

Regarding the palæontological divisions of the system, my colleague, Mr. Peach, concludes "that the presence of three species of *Olenellus* in the Fucoid-beds and Serpulite grit of the North-West Highlands, nearly allied to the American form *Olenellus Thomsoni*—the type species of the genus—together with *Hyolithes*, *Salterella*, and other organisms found with it, prove that these beds represent the Georgian terrane of America, which, as shown by Walcott, underlies the *Paradoxides* zone." Hence he infers that there can be no doubt of the Lower Cambrian age of the beds yielding the *Olenellus* fauna in the North-West Highlands. Mr. Peach further confirms Salter's opinion as to the American facies of the fossils obtained from the higher fossiliferous zones of the Durness dolomite and limestone. He states that "the latter fauna is so similar to, if not identical with, that occurring in Newfoundland, Mingan Islands, and Point Levis, beneath strata yielding the *Phyllograptus* fauna of Arenig age, that the beds must be regarded as belonging to the higher divisions of the Cambrian formation."

The intrusive igneous rocks of the Assynt region, of later date than Cambrian time, and yet older than the Post-Cambrian movements, have been specially studied by Mr. Teall, who has obtained results of special importance from a petrological point of view. This petrographical province embraces the plutonic complex of Cnoc na Sroine and Loch Borolan, and the numerous sills and dykes that traverse the Cambrian and Torridonian sediments, and even the underlying platform of Lewisian gneiss. He infers that the plutonic rocks have been formed by the consolidation of alkaline magmas rich in soda. At the one end of the series is the quartz-syenite of Cnoc na Sroine, and at the other the basic augite-syenite, nepheline-syenite, and borolanite. The basic varieties occur on the margin, and the acid varieties in the centre. The sills and dykes comprise two well-marked types, camptonites or vogesites, and felsites with alkali felspar and ægirine, which he believes to represent the dyke form of the magmas that gave rise to the plutonic mass.[3]

The striking feature in the geology of the North-West Highlands is the evidence relating to those terrestrial movements that affected that region in Post-Cambrian times, which are without a parallel in Britain. The geological structures produced by these displacements are extremely complicated, but the vast amount of evidence obtained in the course of the

[1] Geol. Mag., Dec. III, Vol. V (1888), pp. 484–487.
[2] Quart. Journ. Geol. Soc., vol. xliv, p. 62.
[3] Geol. Mag., Dec. IV, Vol. VII (1900), p. 385.

survey of that belt clearly proves that, though the sections vary indefinitely along the line of complication, they have certain features in common which throw much light on the tectonics of that mountain chain. Some of these features may thus be briefly summarized :—

1. By means of lateral compression or earth-creep the strata are thrown into a series of inverted folds which culminate in reversed faults or thrusts.

2. Without incipient folding, the strata are repeated by a series of minor thrusts or reversed faults which lie at an oblique angle to the major thrust-planes and dip in the direction from which the pressure came, that is, from the east.

3. By means of major thrusts of varying magnitude the following structures are produced : (*a*) the piled-up Cambrian strata are driven westwards along planes formed by the underlying undisturbed materials ; (*b*) masses of Lewisian gneiss, Torridon Sandstone, and Cambrian rocks are made to override the underlying piled-up strata ; (*c*) the Eastern Schists are driven westwards and, in some cases, overlap all major and minor thrusts till they rest directly on the undisturbed Cambrian strata.

When to these features are added the effects of normal faulting and prolonged denudation, it is possible to form some conception of the evolution of those extraordinary structures which are met with in that region. Some of the features just described occur in other mountain chains affected by terrestrial movement, as in the Alps and in Provence ; but there is one which appears to be peculiar to the North-West Highlands. It is the remarkable overlap of the Moine Thrust-plane—the most easterly of the great lines of displacement. Along the southern confines of the wild and complicated region of Assynt, that plane can be traced westwards for a distance of six miles to the Knockan cliff, where the micaceous flagstones rest on the Cambrian Limestone. In Durness we find an outlier of the Eastern Schists reposing on Cambrian Limestone, there preserved by normal faults, at a distance of about ten miles from the mass of similar schists east of Loch Eriboll, with which it was originally continuous.

Though many of these structures appear incredible at first, it is worthy of note that some have been reproduced experimentally by Mr. Cadell.[1] He took layers of sand, loam, clay, and plaster of Paris, and after the materials had set into hard brittle laminæ, in imitation of sedimentary strata, he applied horizontal pressure under varying conditions. The results, some of which may here be given, were remarkable.

1. The compressed mass tends to find relief along a series of gently inclined thrust-planes, which dip towards the side from which pressure is exerted.

2. After a certain amount of heaping up along a series of minor thrust-planes, the heaped-up mass tends to rise and ride forward bodily along major thrust-planes.

3. The front portion of a mass being pushed along a thrust-plane tends to bend over and curve under the back portion.

4. A thrust-plane below may pass into an anticline above ; and a major thrust-plane above may and probably always does originate in a fold below.

Now these important experiments confirm the conclusion reached by the Geological Survey from a study of the phenomena in the field, viz., that under the influence of horizontal compression or earth-creep the rocks in that region behaved like brittle rigid bodies which snapped across, were piled up, and driven westwards in successive slices. But, further, these displacements were accompanied by differential movement of the materials which resulted in the development of new structures. These phenomena culminate along the belt of rocks in immediate association with the Moine

[1] Trans. Roy. Soc. Edinburgh, vol. xxxv, p. 337.

Thrust, where the outcrop of that thrust lies to the east of a broad belt of displaced materials. There, Lewisian gneiss, Torridon Sandstone, and Cambrian quartzite are sheared and rolled out, presenting new divisional planes parallel with that of the Moine Thrust. The Lewisian gneiss shades into flaser gneiss and schist, and ultimately passes into a banded rock like a platy schist. The pegmatites show fluxion structure with felspar 'eyes' like that of the rhyolites. At intervals in these zones of highly sheared rocks, phacoidal masses of Lewisian gneiss appear, in which the Pre-Torridonian structures are not wholly effaced. The sills of camptonite and felsite intrusive in the Cambrian rocks become schistose, and together with the sediments in which they occur appear in a lenticular form. All these mylonized rocks show a characteristic striping on the divisional planes, due to orientation of the constituents in the direction of movement.

Still more important evidence in relation to the question of regional metamorphism is furnished by the Torridon Sandstone. In the case of the basal conglomerate the pebbles have been flattened and elongated, and a fine wavy structure has been developed in the matrix. In the district of Ben More, Assynt, planes of schistosity, more or less parallel with the planes of the Ben More Thrust, pass downwards from the Torridon conglomerate into the underlying gneiss. Both have a common foliation irrespective of the unconformability between them. Again, along the great inversion south of Stromeferry, foliation has been developed in the Torridon conglomerate and overlying Lewisian gneiss, parallel to the plane of the Moine Thrust. The Torridon grits and sandstones south of Kinlochewe and between Kishorn and Loch Alsh are similarly affected by the Post-Cambrian movements. Mr. Teall has shown that the quartz grains have been drawn out into lenticles and into thin folia that wind round 'eyes' of felspar. A secondary crypto-crystalline material has been produced, sericitic mica appears in the divisional planes, and in some instances biotite is developed. In short, he concludes that in these deformed Torridonian sediments there is an approximation to the crystalline schists of the Moine type. The stratigraphical horizon of these rocks can be clearly proved. The subdivisions of the Torridon Sandstone have been recognized in those displaced masses which lie to the east of the Kishorn Thrust and to the west of the Moine Thrust. It is worthy of note also that in the belt of highly sheared gneiss south of Stromeferry that comes between the Torridonian inversion in the west and the Moine Thrust on the east Mr. Peach has found folded and faulted inliers of the basal division of the Torridon Sandstone that have a striking resemblance to typical Moine schists.

Regarding the age of these Post-Cambrian movements, it is obvious that they must be later than the Cambrian Limestone and older than the Old Red Sandstone, for the basal conglomerates of the latter rest unconformably on the Eastern Schists, and contain pebbles of basal quartzite, pipe-rock, limestone, and dolomite derived from the Cambrian rocks of the North-West Highlands.

East of the Moine Thrust or great line of displacement extending from Eriboll to Skye, we enter the wide domain of the metamorphic rocks of the Highlands, a region now under investigation, and which presents difficult problems for solution. Two prominent types of crystalline schists (Caledonian series, Callaway, and Moine schists of the Geological Survey) have been traced over wide areas in the counties of Sutherland, Ross, and Inverness, and across the Great Glen to the northern slopes of the Grampians. Consisting of granulitic quartzose schists and muscovite-biotite schist or gneiss, they appear to be of sedimentary origin, though crystalline. They are associated with recognizable masses of Lewisian

gneiss covering many square miles of ground and presenting many of the structures so characteristic of that complex in the undisturbed areas already described. Within the belt of Lewisian gneiss at Glenelg Mr. Clough has mapped a series of rocks presumably of sedimentary origin, including graphitic schists, mica schists, and limestones, but the gneiss with which they are associated possesses granulitic structure like that of the adjoining Moine schists.[1] Further, in the east of Sutherland, and also in the county of Ross, foliated and massive granites appear which are interleaved in the adjoining Moine schists, forming injection gneisses and producing contact metamorphism.[2]

In the Eastern Highlands the Moine series disappears and is replaced by a broad development of schists, admittedly of sedimentary origin, which have been termed the Dalradian series by Sir A. Geikie. Within recent years it has been divided into certain rock-groups which have been traced by the Geological Survey from the counties of Banff and Aberdeen to Kintyre. It has been found that, though highly crystalline in certain areas, they pass along the strike into comparatively unaltered sediments, as proved by Mr. Hill in the neighbourhood of Loch Awe.[3] Before the planes of schistosity were developed in these Dalradian schists they were pierced by sills of basic rock (gabbro and epidiorite) and acid material (granite), both of which must have shared in the movements that affected the schists, as they merge respectively into hornblende schists and foliated granite or biotite gneiss. Both seem to have developed contact metamorphism ; indeed, Mr. Barrow[4] contends that the regional metamorphism so prominent in the South-East Highlands is mainly, if not wholly, due to the intrusion of an early granite magma, now exposed at the surface in the form of local bosses of granite and isolated veins of pegmatite.

The age of the Dalradian schists has not been determined. Though there seems to be an apparent order of superposition, in this series it is still uncertain whether that implies the original sequence of deposition. Since Sir A. Geikie applied the term Dalradian to the Eastern Highland schists in 1891,[5] evidence has been obtained[6] that suggests the correlation of certain rocks along the Highland border with the Arenig and younger Silurian strata of the Southern Uplands. Consisting of epidiorite, chlorite schist, radiolarian cherts, black shales, grits, and limestone, they have been traced at intervals from Arran to Kincardineshire. In the latter region Mr. Barrow contends that they are separated by a line of disruption from the Highland schists to the north ; but no such discordance has been detected in the Callander district or in Arran. Though these rocks of the Highland border have been much deformed, yet their occurrence in the same order of succession in that region and in the Southern Uplands is presumptive evidence for their correlation.

In view of this evidence it is not improbable that the Dalradian series may contain rock-groups belonging to different geological systems. Indeed, the result of recent Survey work in Islay tends to support this view. For in the south-west part of that island there is a mass of Lewisian gneiss overlaid unconformably by sedimentary strata which have been correlated with the lower and middle divisions of the Torridon Sandstone. Unfortunately the sequence ends here, as both the gneiss and overlying

[1] Summary of Progress Geol. Surv. 1897, p. 37.

[2] "On Foliated Granites and their Relations to the Crystalline Schists in Eastern Sutherland": Quart. Journ. Geol. Soc., vol. lii, p. 633.

[3] Ann. Rep. Geol. Surv., 1893, p. 265.

[4] "Intrusion of Muscovite-biotite Gneiss in the South-East Highlands and its accompanying Metamorphism": Quart. Journ. Geol. Soc., vol. xlix, p. 330.

[5] Quart. Journ. Geol. Soc., vol. xlvii, p. 72.

[6] Ann. Rep. Geol. Surv., 1893, p. 266; 1895, p. 25; 1896, p. 27.

sediments are separated by a line of disruption or thrust-plane from the strata in the eastern part of the island. And yet, notwithstanding this break, the evidence obtained in the latter district is remarkable, whatever theory be adopted to explain it. There the Islay limestone and black slates appear to be covered unconformably by the Islay quartzite containing Annelid tubes and followed in ascending sequence by Fucoidal shales and dolomites, suggestive of the Cambrian succession in Sutherland and Ross. The Islay quartzite passes into Jura, thence to the mainland, and it may eventually prove to be the Perthshire quartzite, while the Islay limestone and black slate are supposed to be the prolongations of the limestone and slate of the Loch Awe series in Argyllshire.[1]

From the foregoing data it will be seen that much uncertainty prevails regarding the age and structural relations of the metamorphic rocks of the Highlands, but the difficulties that here confront the observer are common to all areas affected by regional metamorphism.

A prominent feature in the geology of the Eastern Highlands is the great development of later plutonic rocks chiefly in the form of granite ranging along the Grampian chain from Aberdeenshire to Argyllshire. In connection with one of these masses a remarkable paper appeared in 1892 which in my opinion has profoundly influenced petrological inquiry in Scotland from the light which it threw on the relations of a connected series of petrographical types in a plutonic complex. I refer to the paper on the "Plutonic Rocks of Garabal Hill and Meall Breac," by Mr. Teall and Mr. Dakyns.[2]

The authors showed that this plutonic mass comprises granite, tonalite, augite-diorite, picrites, serpentine, and other compounds. Mr. Teall regards the members of this sequence as products of one original magma by a process of differentiation, the peridotites being the oldest rocks, because the minerals of which they are composed are the first to form in a plutonic magma. As the process of consolidation advances, rocks of a varied composition arise, in the order of increasing acidity, viz., diorites, tonalites, and granites. The most acid rock consists of quartz and orthoclase, which may represent the mother liquor after the other constituents had separated out. Mr. Teall concludes that progressive consolidation of one reservoir gives rise to the formation of magmas of increasing acidity, and hence that basic rocks should precede the acid rocks. This theory of magmatic differentiation—so strenuously advocated by Brögger, Vogt, Rosenbusch, Iddings, Teall, and others—was first applied to the interpretation of varied types of plutonic masses in Scotland by Mr. Teall in the paper referred to. Since then he has extended its application to the granite masses in the Silurian tableland of the south of Scotland, which include rocks ranging from hyperites at the one end to granitite with microcline and aplite veins at the other.[3] Many of the phenomena presented by the newer granite masses of the Eastern Highlands seem to lend support to this theory. These views, indeed, have permeated the petrological descriptions of the granitic protrusions in the counties of Aberdeen and Argyll which have been given by Messrs. Barrow, Hill, Kynaston, and Craig[4] in recent years.

One of the remarkable advances in Scottish geology during the period under review is the solution of the order of succession and tectonic

[1] Summary of Progress Geol. Surv. 1899, p. 66.

[2] Quart. Journ. Geol. Soc., vol. xlviii, p. 104.

[3] Ann. Rep. Geol. Surv., 1896, p. 40; see also "The Silurian Rocks of Scotland," Geol. Surv. Memoir, 1899, p. 607.

[4] Ann. Rep. Geol. Surv., 1897, p. 87; 1898, pp. 25–28. See also paper on "Kentallenite and its Relations to other Igneous Rocks in Argyllshire": Quart. Journ. Geol. Soc., vol. lvi, p. 531.

relations of the Silurian rocks of the south of Scotland by Professor Lapworth. The history of research relating to that tableland, and of all his contributions to the problems connected with it, has been given in detail in the recent volume of the Geological Survey on that formation. At present it will be sufficient to refer to his three classic papers, which, in my opinion, record one of the great achievements in British geology. The first, on "The Moffat Series,"[1] demonstrated, by means of the vertical distribution of the graptolites, the order of succession in those fine deposits (black shales and mudstones), which were laid down near the verge of sedimentation, and are now exposed in anticlinal folds in the central belt. The second, on "The Girvan Succession,"[2] showed how certain graptolite zones of the Moffat shales are interleaved, in the Girvan region, with conglomerates, grits, sandstones, flagstones, mudstones, shales, and limestones, charged with all the varied forms of life found in shallow seas or near shore. In the third, on "The Ballantrae Rocks of the South of Scotland and their Place in the Upland Sequence,"[3] he indicated the distribution and variation of the Moffat terrane (Upper Llandeilo to Upper Llandovery) and of the Gala terrane (Tarannon), which form the greater part of the uplands. He further pointed out how the rocks and the fossils vary across the uplands according to the conditions of deposition. Finally, he proved that the complicated tectonics of the Silurian tableland, its endless overfolds, its endoclinal and exoclinal structures, can be unravelled by means of the graptolite zones. These researches disposed of the order of succession based on Barrande's doctrine of Colonies, and established the zonal value of graptolites as an index of stratigraphical horizons. So complete was the zonal method of mapping adopted by Professor Lapworth, and so accurate were his generalizations, that few modifications have been made in his work.

In the course of the re-examination of the Silurian tableland by the Geological Survey some important additions were made to our knowledge of the Silurian system as there developed. Underlying all the sediments of the uplands there is a series of volcanic and plutonic rocks of Arenig age, the largest development of which occurs at Ballantrae in Ayrshire, where their igneous character was recognized by Professor Bonney. But they appear in the cores of numerous anticlines over an area of about 1,500 square miles, forming one of the most extensive volcanic areas of Palæozoic age in the British Isles. These volcanic rocks are overlain by a band of cherts and mudstones, succeeded by black shales yielding Glenkiln graptolites of Upper Llandeilo age. The cherts, which are abundantly charged with Radiolaria, implying oceanic conditions of deposition, are about 70 feet thick, and have been traced over an area of about 2,000 square miles. The deposition of the Radiolarian ooze must have occupied a long lapse of time. Indeed, the cherts and mudstones represent the strata which, in other regions, form the Upper Arenig and Lower Llandeilo divisions of the Silurian system. They furnish interesting evidence of the oceanic conditions which here prevailed in early Silurian time, and form a natural sequel to Professor Lapworth's researches bearing on the graptolitic deposits of the Upper Llandeilo period, which must have been laid down on the sea-floor near the limit of the land-derived sediment.

Of special interest is the new fish fauna found by the Geological Survey in the Ludlow and Downtonian rocks between Lesmahagow and Muirkirk, which the researches of Dr. Traquair have shown to be of great biological and palæontological value.[4] This discovery has enabled

[1] Quart. Journ. Geol. Soc., vol. xxxiv, p. 240.
[2] Ibid., vol. xxxviii, p. 537.
[3] Geol. Mag., Dec. III, Vol. VI (1889), p. 20.
[4] Trans. Roy. Soc. Edinb., vol. xxxix, p. 827.

him to give a new classification of the Ostracodermi, and to enlarge the order of the Heterostraci, which now includes four families, instead of the Pteraspidæ alone. He has further shown that the Cœlolepidæ were not Cestracionts sharks to which the *Onchus* spines belonged, but Heterostraci, though probably of Elasmobranch origin, judging from the shagreen-like scales. The Cœlolepidæ are common fishes in the Ludlow and Downtonian rocks of Lanarkshire. The genus *Thelodus*, first described by Agassiz from detached scales in the Ludlow bone-bed, and subsequently figured and described by Pander and Rohon from scales in the Upper Silurian rocks of Oesel, is here represented for the first time by nearly complete forms. But it is remarkable that no *Onchus* spines, nor any Pteraspidæ, nor Cephalaspidæ have been found in the Lanarkshire strata, the nearest related genus to *Cephalaspis* being *Ateleaspis*, which, however, represents a distinct family.

The group of sandstones, conglomerates, shales, and mudstones that form the passage-beds between the Ludlow rocks and the Lower Old Red Sandstone in Lanarkshire are now regarded as the equivalents of the Downtonian strata in Shropshire, and are linked with the Silurian system. The mudstones of this group, containing the new fish fauna, likewise yield ostracods, phyllocarid crustaceans, and eurypterids—forms which connect these beds with the underlying Ludlow rocks. The band of greywacke-conglomerate, that extends from the Pentland Hills into Ayrshire, composed largely of pebbles derived from the Silurian tableland, is now taken as the base-line of the Lower Old Red Sandstone on the south side of the great midland valley of Scotland.

The period under review has been marked by important additions to our knowledge of the Old Red Sandstone formation. In 1878 appeared a valuable monograph by Sir Archibald Geikie on "The Old Red Sandstone of Western Europe,"[1] by far the most important treatise on this subject since the publication of Hugh Miller's classic work in 1841. Following up the view maintained by Fleming, Godwin-Austen, and Ramsay, that the deposits of this formation were laid down in lakes or inland seas, he defined the geographical areas of the various basins in the British area, giving to each a local name. He gave an outline of the development of the rocks north of the Grampians in Caithness, Orkney, and Shetland. He advanced an ingenious argument in favour of correlating the Caithness flagstone series (middle division, Murchison) with the Lower Old Red Sandstone south of the Grampians. He contended that "the admitted palæontological distinctions between the two areas are probably not greater than the striking lithological differences between the strata would account for, or than the contrast between the ichthyic faunas of adjacent but disconnected water basins at the present time." Sir A. Geikie further gave a table showing the vertical range of the known fossils of the Caithness series from data partly supplied by the late Mr. C. Peach.

During the last quarter of a century Dr. Traquair has made a special study of the ichthyology of the Old Red Sandstone and Carboniferous strata of Scotland, which has enabled him to throw much light on the distribution of fossil fishes in these rocks and on their value for the purpose of correlation. His researches show that the fish fauna of the formation south of the Grampians resembles that of the Lower Old Red Sandstone of the West of England and adjoining part of Wales in the abundance of specimens of *Cephalaspis*, the common species in Forfarshire (*C. Lyelli*, Ag.) being also indistinguishable from that in the Herefordshire beds. *Pteraspis* occurs in both regions, though of different species. Of Acanthodians *Parexus recurvus*, Ag., occurs in both, together with

[1] Trans. Roy. Soc. Edinb., vol. xxviii, p. 345.

Climatius (*C. ornatus*, Ag.). The abundance of *Cephalaspis* (*C. Campbelltonensis*, Whit., *C. Jexi*, Traq.) and of *Climatius* spines is characteristic of the Lower Devonian rocks of Canada.

The Old Red Sandstone of Lorne has recently yielded organic remains, akin to those found in Forfarshire, south of the Grampians, viz. *Cephalaspis Lornensis* (Traq.), and two species of myriapods (*Campecaris Forfarensis* and a species of *Archidesmus*).[1]

In the deposits of Lake Orcadie, north of the Grampians, quite a different fish fauna from that of Forfarshire appears. Dr. Traquair has noted that there are no species common to the two areas, and only two genera, viz. *Mesacanthus* and *Cephalaspis*. The latter genus is, however, represented in Caithness only by a single specimen of a species (*C. magnifica*, Traq.) different from any found elsewhere. It might here be observed that *Cephalaspis* is represented also in the Upper Devonian rocks of Canada by a single specimen of a peculiar species (*C. laticeps*, Traq.), and hence Dr. Traquair has shown that, though *Cephalaspis* is most abundant in the Lower Devonian, it extends also into the upper division of that system. It further appears that Osteolepidæ (*Osteolepis*, *Diplopterus*), Rhizodontidæ (*Tristichopterus*, *Gyroptychius*), Holoptychiidæ (*Glyptolepis*), Asterolepidæ (*Pterichthys*, *Microbrachius*), Ctenodontidæ (*Dipterus*) are abundant in the Orcadian fauna, none of which has occurred in the Lower Old Red Sandstone of Forfarshire, the West of England, or in the Lower Devonian rocks of Canada. Dr. Traquair recognized, however, the identity of the fishes from the well-known fish band in the basin of the Moray Firth with those brought from the west part of Orkney, though these forms did not quite agree with the fossils from the Thurso district. He subsequently found that the fish fauna from the Orcadian beds in the Moray Firth basin is represented in Caithness by that of Achanarras; and, further, that two other faunas occur in the Caithness area—that of Thurso and that of John o' Groats, as given below :—

John o' Groats . . .	*Tristichopterus alatus*, Egert. *Microbrachius Dicki*, Traq.
Thurso	*Coccosteus minor*, H. Miller. *Thursius pholidotus*, Traq. *Osteolepis microlepidotus*, Pander.
Achanarras	*Pterichthys*, three species. *Cheirolepis Trailli*, Ag. *Osteolepis macrolepidotus*, Ag.

In 1898 appeared an important paper by Dr. Flett on "The Old Red Sandstone of the Orkneys,"[2] in which he described the results of his detailed examination of the islands. He proved the existence there of three fish faunas, and their correspondence with those identified in Caithness by Dr. Traquair. From the evidence in the field he adopted the following order of succession and correlation of the strata :—

3. Eday Sandstones and John o' Groats beds.
2. Rousay and Thurso beds.
1. Stromness, Achanarras, and Cromarty beds.

A further important result of Dr. Flett's researches in the Old Red Sandstone of these northern isles was communicated to the Royal Society of Edinburgh this year. He has found in the Shetland beds, which had previously yielded no fossils save plants, fragments, identified by Dr. Traquair as *Holonema*, a fish new to Britain, but occurring in the Chemung group of North America, the subdivision of the Upper Devonian that immediately underlies the Catskill red sandstones, with remains of

[1] Summary of Progress Geol. Surv. 1897, p. 83.
[2] Trans. Roy. Soc. Edinb., vol. xxxix, p. 383.

Holoptychius. Dr. Traquair has also recognized in Dr. Flett's collection fragments of *Asterolepis*, a genus characteristic of the Upper Old Red Sandstone, and which, as proved by Dr. Flett, occurs in the 'Thurso beds' of the Orkneys. The interest attaching to this discovery is very great, for Dr. Flett contends that it indicates a fourth life-zone in the Orcadian series, and, further, that it tends to span the break between the Orcadian division and Upper Old Red Sandstone.

In the Upper Old Red Sandstone on the south side of the Moray Firth, Dr. Traquair recognized two life-zones, and subsequently, with the assistance of Mr. Taylor, Lhanbryde, a third; in the following order. The lowest is that of the Nairn sandstones with *Asterolepis maxima* (Ag.); the second, that of Alves and Scaat Craig with *Bothriolepis major* (Ag.), *Psammosteus Taylori* (Traq.); and the highest, that of Rosebrae, the fauna of which, according to Dr. Traquair, has a striking resemblance to the assemblage in the Dura Den Sandstones in Fife.

Before 1876 all the Carboniferous areas in the great midland valley of Scotland had been mapped by the Geological Survey. The extent and structural relations of the various coalfields were determined according to the information then available, and shown in the published maps. But the rapid development of certain fields in the east of Scotland necessitated a revision of them, which has lately been done. The Fife Coalfield has been re-examined by Sir A. Geikie, Mr. Peach, and Mr. Wilson, and the oil-shale fields in the Lothians have been mapped by Mr. Cadell. An important memoir by Sir A. Geikie on "The Geology of Central and Western Fife and Kinross" has just been issued by the Geological Survey, in which the structure of these coalfields is described. Mr. Cadell lately gave an account of the geological structure of the oil-shale fields in his presidential address to the Edinburgh Geological Society.

Within the period under review detailed researches of great importance on the fossil flora of British Carboniferous rocks have been carried out by Mr. Kidston, to which reference ought to be made. The results are of the highest value for correlating the strata in different areas.[1] By means of the plants he arranges the Carboniferous rocks of Scotland in two great divisions: a lower, comprising the Calciferous Sandstone and Carboniferous Limestone series; and an upper, including the Millstone Grit and the Coal-measures, there being a marked palæontological break at the base of the Millstone Grit. He shows that the upper and lower divisions of the system, not only in Scotland but in Britain, are characterized by a different series of plants, not one species passing from the lower division, save in the case of *Stigmaria*, into the upper. From his researches it appears that, among ferns, *Neuropteris* is all but unknown in the lower division, whereas in the upper it is very abundant. The Sphenopterids are proportionately common in both divisions; but those of the lower are usually characterized by cuneate segments, while those of the upper have generally rounded pinnules. *Alethopteris*, so common throughout the whole of the upper series, is entirely absent from the lower. The genus *Calamites*, which is extremely plentiful in the upper, is almost entirely absent from the lower division, where its place is taken by *Asterocalamites*. The *Cordaiteæ* are also rare below the Millstone Grit, though very plentiful above that horizon. *Sigillaria*, so rare in the Lower Carboniferous rocks, is extremely abundant in the upper division, and particularly in the middle Coal-measures. In short, Mr. Kidston concludes that the floras of the two main divisions of the Carboniferous system, though belonging to the same types, are absolutely distinct in species and in the relative importance of the genera.

[1] "On the various Divisions of British Carboniferous Rocks as determined by their Fossil Flora": Proc. Roy. Phys. Soc. Edinb., vol. xii (1893), p. 183.

By means of the fossil plants Mr. Kidston correlates the Coal-measures of Scotland underlying the red sandstones with the lower division of the Coal-measures of England, and the overlying red sandstones of Fife with the middle division of the English Coal-measures.

It is remarkable that the evidence supplied by the fossil fishes has led Dr. Traquair independently to a similar conclusion. He holds that fossil ichthyology proves the existence of only two great life-zones in the Carboniferous rocks of Central Scotland—an upper and a lower—the boundary-line between the two being drawn at the base of the Millstone Grit. The Scottish Carboniferous rocks, being mostly estuarine, give an opportunity of comparing the estuarine fishes of both divisions. He finds the Coal-measure fishes of Scotland to be the same as those in the English Coal-measures, while those occurring below the Millstone Grit in Scotland are mostly different in species, and often, too, in genera, from the forms above that horizon.

Of special interest, as bearing on the former extension of this system in Scotland, is the discovery made by Professor Judd [1] in 1877 of a patch of Carboniferous sandstones and shales, with well-preserved plant remains in Morven. Another small outlier of this formation has recently been found in the Pass of Brander by the Geological Survey.[2]

The reptiles from the Elgin sandstones, recently described by Mr. E. T. Newton,[3] add fresh interest to the study of these rocks. The structural relations of these sandstones have been fully treated by Professor Judd in his great paper on the Secondary Rocks on the East of Scotland,[4] and again in his presidential address to this Section at Aberdeen,[5] who confirmed Huxley's well-known correlation of these beds with the Trias. The Dicynodont skull, identified by Professor Judd and Dr. Traquair at the Aberdeen meeting of the British Association in 1885, and other remains found in the reptilian sandstones in Cutties Hillock Quarry, where they rest on Upper Old Red Sandstone with *Holoptychius*, have been described by Mr. Newton. He confirmed their affinity with Dicynodonts, though they were referred to the genera *Gordonia* and *Geikia*. But the most remarkable specimen was the skull named by Mr. Newton *Elginia mirabilis*. This extraordinary creature, with a pair of horns projecting like those of a short-horned ox, and with smaller spines and bosses, numbering thirty-nine, is related to the great *Pareiasaurus* from the Karoo beds of South Africa. Two other reptiles are described by Mr. Newton from this quarry, namely, a small crocodile-like animal, *Erpetosuchus Granti*, apparently nearly allied to *Stagonolepis*, and *Ornithosuchus Woodwardi*, which is probably a small Dinosaurian.

Mr. Newton has raised an interesting point in connection with his researches. He calls attention to the fact that the reptilian remains from the Cutties Hillock Quarry differ from those found at other localities in the Elgin district. For example, the Lossiemouth sandstones have yielded *Stagonolepis*, *Hyperodapedon*, and *Telerpeton*; and the Cutties Hillock sandstones, the Dicynodonts (*Gordonia* and *Geikia*), the horned reptile (*Elginia*), the small crocodile-like *Erpetosuchus*, and the little Dinosaurian *Ornithosuchus*. Does this distribution indicate different stratigraphical horizons? is virtually the point raised by Mr. Newton. In connection with this inquiry he cites the evidence obtained in other countries. Thus, in the Gondwana beds of India, the series of reptiles similar to those of Elgin occur at different localities and on different

[1] Quart. Journ. Geol. Soc., vol. xxxiv, p. 685.
[2] Summary of Progress Geol. Surv. 1898, p. 129.
[3] Phil. Trans., vol. clxxxiv (1893), p. 431; ibid., vol. clxxxv (1894), p. 573.
[4] Quart. Journ. Geol. Soc., vol. xxix, p. 98.
[5] Rep. Brit. Assoc., 1885, p. 994.

stratigraphical horizons Dicynodonts and Labyrinthodonts being found in the lower Panchet rocks, while *Hyperodapedon* and *Parasuchus* (allied to *Stagonolepis*) are met with in the higher Kota-Maleri beds. Again, in the Karoo beds of South Africa the Dicynodonts and the great *Pareiasaurus*—the latter being the nearest known ally of the horned reptile (*Elginia mirabilis*) from Cutties Hillock, Elgin—occur low down in that formation. Further light is thrown on the question by the interesting discoveries of Amalitzky in Northern Russia, where a number of reptilian remains have been found closely allied to *Pareiasaurus*, *Elginia*, and *Dicynodon*, in beds which are referred to the Permian formation, and accompanied by plants and mollusca which seemingly confirm this reference.[1]

In view of these foreign discoveries Mr. Newton concludes that the Elgin sandstones may probably represent more than one reptilian horizon, and that we are confronted with the possibility of their being of Permian age.

The difficulty of drawing a boundary-line between the Trias and the Upper Old Red Sandstone of Elgin, which impressed the mind of the late Dr. Gordon, has had to be faced elsewhere in Scotland. In Arran, my colleague Mr. Gunn has shown that the Trias there rests on the Upper Old Red Sandstone, both formations having a similar inclination. Even he, with his ripe experience, has had great difficulty in drawing a boundary between them on the west side of the island ; but when the base-line of the Trias is traced eastwards to Brodick it passes transgressively on to Carboniferous rocks.

Of special importance is the recent discovery in Arran of the fossils of the *Avicula contorta* zone[2] by Mr. Macconochie, of the Geological Survey, to whose skill as a fossil collector Scottish geology owes much. With these occur Lower Liassic fossils, in sediments which are not now found in place in the island. These fossiliferous patches are associated with fragmental volcanic materials filling a great vent, the age of which will be referred to presently. This discovery has fixed the Triassic age of the red sandstones and marls in the south of Arran. The detailed mapping of the island by Mr. Gunn has demonstrated that the Triassic sandstones rest partly on the Old Red Sandstone, partly on the Carboniferous Limestone Series, and partly on the Coal-measures.

In 1878 appeared the third of Professor Judd's great papers on the Secondary Rocks of Scotland, wherein he unravelled the history of these strata as developed in the east of Scotland and in the West Highlands. His admirable researches, in continuation of the work done by Bryce, Tate, and others, embraced the identification of the life-zones, their correlation with those of other regions, the history of the physical conditions which prevailed in Scotland during Mesozoic time, and the working out of the structural relations of the strata.[3] He showed that their preservation on the east of Scotland was due to the existence of great faults, and those in the West Highlands to the copious outpouring of the Tertiary lavas. He was the first to detect the occurrence of Cretaceous rocks in the West Highlands, and to show the marked unconformability which separates them from the Jurassic strata. His main life-zones and his main conclusions regarding the Secondary Rocks of Scotland have so far been confirmed by the detailed mapping of the Geological Survey. An interesting addition to our knowledge of these rocks was made by my colleague Mr. Horace B. Woodward, in the course of his field-work, who

[1] Y. Amalitzky: "Sur les fouilles de 1899 de débris de vertébrés dans les dépôts Permiens de la Russie du nord," Varsovie, 1900.

[2] Summary of Progress Geol. Surv. 1899, p. 133.

[3] Quart. Journ. Geol. Soc., vol. xxix, p. 97 ; vol. xxxiv, p. 660.

found the oolitic iron-ore in the Middle Lias of Raasay, the position of which corresponds approximately with that of the Cleveland ironstone.[1]

The extensive plateau of Tertiary volcanic rocks in the Inner Hebrides has been a favourite field of research ever since the time of Macculloch, the great pioneer in West Highland geology. During the period under review much work has been done in that domain. According to Professor Judd, that region contains the relics of five great extinct volcanoes and several minor cones, indicating three periods of igneous activity. The first was characterized by the discharge of acid lavas and ashes, the molten material consolidating down below as granite; the second by the outburst of basic lavas, now forming the basaltic plateau, connected with deep-seated masses that appear now as gabbro and dolerite; the third by the appearance of sporadic cones, from which issued minor streams of lava.[2]

In 1888 Sir A. Geikie communicated his elaborate monograph on the history of Tertiary volcanic action in Britain to the Royal Society of Edinburgh,[3] which has been incorporated, with fuller details, in his recent work on "The Ancient Volcanoes of Great Britain." His main conclusions may thus be briefly stated: (1) The great basaltic plateaux did not emanate from central volcanoes, but are probably due to fissure eruptions; (2) the basaltic lavas were subsequently pierced by laccolitic masses of gabbro, which produced a certain amount of contact alteration on the previously erupted lavas; (3) the protrusion of masses of granophyre and other acid materials by means of which the basic rocks were disrupted.

During the last six years Mr. Harker has been engaged in mapping the central part of the Isle of Skye and in the petrographical study of the rocks, the results of which have been summarized in the annual reports of the Geological Survey. As regards the basaltic lavas, he finds that while they have been of vast extent the individual flows have been of feeble volume, and show no evident relation to definite centres of eruption. There were two local episodes, however, which took the form of central eruptions: one represented by a number of explosive outbursts at certain points; the other, in the basalt succession, gave rise to rhyolitic rocks.

Mr. Harker further finds that the succeeding plutonic phase of activity, confined in Skye to what is now the central mountain tract, is represented by three groups of plutonic intrusions, in the following order: peridotites, gabbros, and granites. The metamorphism set up in the basaltic lavas near the large plutonic masses presents points of interest, especially the widespread formation of new lime-soda-felspars from the zeolites in the lavas.

After the intrusion of the granite of the Red Hills, Mr. Harker finds that igneous activity took the form of intrusions of smaller volume, but in some cases of wide distribution. The great group of dolerite sills belongs to this period. An enormous number of acid and basic dykes followed, of several distinct epochs. A set of minor basic intrusions of quite late date is found in the gabbro district of the Cuillins, the most interesting of which takes the form of sheets of dolerite, parallel at any given locality, but always dipping towards the centre of the gabbro area. Mr. Harker considers that this remarkable system of injections presents a new problem in the mechanics of igneous intrusion. The latest phase of vulcanicity in the Cuillin district is a radial group of peridotite dykes. As regards the local group of rock in Central Skye Mr. Harker finds that the order of increasing acidity which ruled in the plutonic phase was reversed for the minor intrusions which followed.

In connection with the great development of volcanic activity in the

[1] Geol. Mag., Dec. III, Vol. X (1893), p. 493.
[2] Quart. Journ. Geol. Soc., vol. xxx, p. 220.
[3] Trans. Roy. Soc. Edinb., vol. xxxv, pt. 2, p. 23.

West of Scotland in Tertiary time reference must be made to the remarkable volcanic vent in Arran, the recognition of which is due to the suggestion of my friend Mr. Peach. This volcanic centre covers an area of about eight square miles, and lies to the south of the granite area of the island.[1] The vent is now filled with volcanic agglomerate and large masses of sedimentary material, some of which have yielded the Rhætic and Lower Lias fossils already referred to, the whole being pierced by acid and basic igneous rocks. One of the interesting features connected with it is the occurrence of fragments of limestone with the agglomerate, which has yielded fossils of the age of the Chalk, thus proving that the vent is post-Cretaceous. There is thus strong evidence for referring the granite mass in the north of the island and most of the intrusive, acid, and basic igneous rocks to the Tertiary period. It furnishes remarkable proof of the Tertiary age of the Arran granite suggested by Sir A. Geikie in 1873.[2] The story unfolded by this discovery is like a geological romance. The former extension of Rhætic and Lower Lias strata and of the Chalk in the basin of the Clyde, and the evidence of extensive denudation in the south of Scotland, appeal vividly to the imagination.

This outline of the researches in the solid geology of Scotland would be incomplete without reference to the publication of Sir A. Geikie's great work on "The Ancient Volcanoes of Great Britain" (1897), in which the history is given of volcanic action in Scotland from the earliest geological periods down to Tertiary time. To investigators it has proved invaluable for reference. Nor can I omit to mention the new edition of his volume on "The Scenery of Scotland," wherein he depicts the evolution of the topography of the country with increasing force and fascination. In this domain it may be said of the author, "Nihil quod tetigit sed ornavit."

II.—Egyptian Geology.—We have much pleasure in noticing "Geological Survey Report, 1899, Part III, Farafra Oasis; its topography and geology, by Hugh J. L. Beadnell," issued in July, 1901, by the Survey Department, Public Works Ministry at Cairo. This, the second report issued, follows closely on Part II, and consists of 39 pp., 4 maps, and many sections. The report is divided into Introduction; Topography, with notes on the Wells, Population, etc.; Geology; the Desert between Farafra and Dakhla; and Geological Summary. The geological summary shows that in the district under notice the lowest rocks met with are correlated with the Danian of Europe. These consist of, from below up, clays and sandstones of Ain el Wadi, with plant remains and silicified wood; hard blue-grey limestones and White Chalk with brachiopods, lamellibranchs, annelids, etc. Above these come shales, occasionally present, with an abundance of fossils, beds probably representing locally the upper part of the White Chalk. The Eocene is represented in its lower part only by limestones of the plateau with numerous echinids, lamellibranchs, and many foraminifera (Libyan series) at the top, while below come the Esna Shales, in part fossiliferous and with *Operculina* limestone occasionally at the base. The recent deposits are seen in the soils and clays of springs with recent fresh-water shells, blown sand, and local and unfossiliferous marls and clays. The report will be of the highest value, and like

[1] Quart. Journ. Geol. Soc., vol. lvii (1901), p. 226.
[2] Trans. Geol. Soc. Edinb., vol. ii, p. 305.

its predecessor is exceedingly well got up; we await the future parts with the greatest interest. One thing we would ask of the Director-General, Captain Lyons, and that is, to allow the word 'Egypt' to appear somewhere on the title-page.

III.—Economic Geology.—Messrs. John C. Branner and John F. Newsom have issued a second edition of their "Syllabus of a course of Lectures on Economic Geology," 1900, in a volume printed on one side of the paper only, of 368 pp. One of the most important things a student of economic geology needs to learn is where to find and how to use information that has been published. The authors have therefore given references, first, to works on the general subject; second, to periodicals in which articles are to be looked for upon various economic subjects; third, to papers and reports on special subjects. Naturally in a book issued by the Professors of the Leland Stanford junior University, more space is given to the economic geology of the United States than to that of other countries. The book has a good index, and is illustrated by a number of charts and sections. The compositions of minerals are mainly taken from Dana.

IV.—Canadian Geology. Sessional Paper No. 26, 64 Victoria, Summary Report of the Geological Survey Department, for the year 1900, is an octavo of 203 pages and forms an important and interesting document. It has, moreover, a melancholy interest in that it is the last report from the pen of the late G. M. Dawson. In this report especial prominence is given to the results of field-work, "thus affording an early publication of a preliminary kind for any new facts obtained," an object that entitles this report to especial attention. During the year 1900 twelve new maps were completed and finished, and eighteen others were either in the engraver's hands or in the press. Mr. James White has completed his Altitudes in the Dominion of Canada, and this will shortly be issued. Attention is again drawn to the inadequate safety of the present Museum and offices. It is a penny-wise-and-pound-foolish policy to allow such precious and costly records to continue exposed to the danger of fire. After a series of reports on economic minerals, a good account is given of the exhibit sent by Canada to the Paris Exhibition, and the report proper opens on p. 37 with a detailed account of the Yukon district. The areas explored are those of the Stewart and Yukon rivers, the coals and lignites of the Klondike river, and the copper deposits of White Horse. From p. 52 work accomplished in British Columbia is detailed, and a map of the Atlin Goldfields is appended, the geology of which is provided by Mr. J. C. Gwillim. Mr. J. M. Bull reviews the explorations carried out in the Mackenzie district, after which the report deals with Canada proper, New Brunswick, and Nova Scotia. As regards zoology, the chief item of interest is the announcement that Professor H. F. Osborn is at work upon the vertebrate remains collected from the Cretaceous rocks of the Red Deer River, and drawings have already been prepared for the report which it is hoped will soon

be issued. Lambe's "Revision of the Genera and Species of the Madreporaria Aporosa and Madreporaria Rugosa" has been published, and Whiteaves' fourth part of Mesozoic Fossils was issued in November, 1900.

V.—Canadian Palæozoic Corals. — Lawrence M. Lambe has issued part ii of his Revision of the Genera and Species of Canadian Palæozoic Corals, as Contributions to Canadian Palæontology, vol. iv, pt. 2. This part deals with the Madreporaria Aporosa and the Madreporaria Rugosa, and consists of 200 pages and 13 plates. The work is of considerable value and seems to have been prepared with much care; there is little new in it, but that perhaps shows more exactly the attention which the author has paid to his predecessors. Perhaps Nicholson's work might have been more carefully studied. We do not grasp the author's reasons for rejecting the genus *Heliophyllum* and placing the species under *Cyathophyllum*, or for using *Arachnophyllum* in the place of *Strombodes*. The monograph is a valuable addition to the literature of the Palæozoic Madreporaria, and we hope the author will be encouraged to continue it.

VI.—Palæozoic Crustacea.—In the 54th annual report of the New York State Museum, 1900 (1901), J. M. Clarke has some notes on new Crustacea. One of these, the peculiar, eyeless, semi-trilobitic merostome, called *Pseudoniscus* by Nieszkowski in 1859, has been found in the *Eurypterus* dolomites of Litchfield, Herkimer County, and is described under the name of *P. Roosevelti*. Some of the American specimens are perfect, and Mr. Clarke has been enabled to add a good deal to our knowledge of the animal. The other new Crustacea described in his paper are *Ceratiocaris præcedens*, *Emmelezoe decora*, and *Estheria Ortoni*; the latter is a Coal-measure form and was found at Carrollton.

VII.—New Geological Map of the Mont Blanc Massif.—Professors Duparc and Mrazec have issued the map to accompany their memoir on Mont Blanc, published in 1898 by the Société Physique et d'Histoire Naturelle de Genève. They had the collaboration of Dr. Pearce for the Val Ferret region and for the Courmayeur synclinal. The map is based on that of Albert Barbey, but includes Mont Catogne; its scale is 1 : 50,000, and it is clearly printed and lightly tinted in colour. The publisher is Comptoir Minéralogique et Géologique Suisse, Minod, 6, Rue St. Léger, Geneva. Price not quoted. The publishers also announce the completion of collections of rocks referred to in Professors Duparc and Mrazec's memoir, 49 specimens for 180 francs.

VIII.—Geology of the Philippine Islands.—The United States Geological Survey has included in its twenty-first annual volume a report on the Geology of the Philippine Islands. The work was entrusted to George F. Becker, who has produced an admirable resumé of the work of all who have gone before, and has added to that observations of his own, taken at considerable disadvantage owing to the unsettled state of the Islands. The report is rather an attempt to bring together all that is known than to provide a new and complete account of the geology of the Philippines. Becker lists

some 100 papers on the subject, and has provided a translation of Martin's paper on the Tertiary Fossils which was published in 1895. He also gives two excellent maps of the Islands, drawn by the Jesuit Fathers, and has utilized a sketch of the mineral resources compiled for him from the archives of the Inspección de Minas by Luis Espina. Becker accompanied General Otis to Manila, and remained in the Islands fourteen months, but could accomplish little original work because of the attitude of the natives. The paper will be very useful to all subsequent workers, and this seems to be its real purpose.

IX.—New Brachiopoda, etc.—(1) Suppl. zu d. Beschreibung der Silurischen Craniaden der Ostseeländer. Friedrich Hoyningen Huene. K. Russ. Mineralog. Gesellsch. zu St. Petersburg, 1900, Ser. II, Bd. xxxviii, No. 1, with 3 plates. (2) Ueber *Aulacomerella*, ein neues Brachiopodengeschlecht. Idem, with plate. (3) Beiträge zur Beurtheilung der Brachiopoden. F. H. Huene. Centralblatt für Mineralogie, etc., 1901, woodcut. (4) Cambrian Brachiopoda: *Obolella*, subgenus *Glyptias*; *Bicia*; *Obolus*, subgenus *Westonia*; with Descriptions of New Species. C. D. Walcott. Proc. U.S. National Museum, 1901, vol. ii.

The first of these four pamphlets contains figures and descriptions of species belonging to different genera of Silurian Craniadæ, illustrations of the shell-structure of two genera, *Pseudocrania* and *Pseudometopoma*, geographic-geologic tables, and other important matter. In the second contribution two species of a new genus, *Aulacomerella*, are described and figured. The genus is said to show senile characters; and also to be a homœomorph of *Aulacorhynchus*, a fact referable, the author suggests, to "repetition of development." The third paper is a later contribution by the same author. It discusses the bearing of certain facts upon studies of Brachiopods, dealing especially with some important anatomical results of F. Blochmann. The author also calls attention to the great confusion in the nomenclature of the shell muscles, pleading for a uniform Latin system. The last paper is a forerunner of a monograph. A new genus, two new subgenera, and several new species are described; but there are no figures. We much regret to find so eminent a palæontologist as Dr. Walcott countenancing so very undesirable a practice.

REVIEWS.

I.—Fauna der Gaskohle und der Kalksteine der Permformation, Bohems. By Dr. Anton Fritsch. Vols. i–iv: pp. 552, 394 text-figures and 165 chromolithographic plates.

AFTER devoting thirty years of almost continuous work to its study and elucidation, the author, Dr. Anton Fritsch, has completed the illustration and description of the Permian Fauna of Bohemia, the marvellous richness of which has surprised all students of palæontology; and we congratulate our distinguished fellow-worker upon having lived to achieve so important an undertaking.

In 1860 only thirteen species of vertebrates were known from these formations in Bohemia ; now 123 species have been recorded, and 66 of invertebrates, making together 189 species, all figured and described.

In monographing and carefully drawing more than sixty species of Stegocephalia, the author has been cautious not to advance any phylogenetic speculations, seeing that the group does not lend much help in explaining the evolution of amphibians, and we are led to the conclusion that a long series of unknown vertebrates must have existed before these formations were deposited—the ancestors, in fact, of these Permian forms.

The osteological details given in this work will certainly prove of great value in future comparative anatomical investigations. The beautifully preserved remains of Dipnoi, including even an entire specimen, demonstrate how little that group has changed from the Carboniferous *Ctenodus* to the living *Ceratodus* of Australia. In the order Selachii the author has adduced important evidence as to the structure of the fins in *Pleuracanthus* (*Xenacanthus*), and his opinion that they have been developed from a series of parallel rays has only a short time subsequently been confirmed by the discovery of the fin of *Cladoselache* in the Upper Devonian of Ohio. Many figures from this work have been reproduced by Wiedersheim and other authors who have written lately on the fins of recent Selachii. The tribe of Acanthodians has been augmented by two new and important genera—*Traquairia* and *Protacanthodes*, which latter is a predecessor of the true Acanthodians of later times. The notes on Silurian Acanthodians are very interesting and most valuable. Amongst the Palæoniscidæ, the new genus *Trissolepis*, with three kinds of scales, is most remarkable, showing the gradual development of the ganoid scales beginning near the tail.

In the fourth volume, which is devoted to the Invertebrata, evidence is brought forward to show that insects with complete metamorphosis were already represented in Palæozoic times by the Trichopteroid genus *Phryanæa* and by the larva of a beetle (*Archicarabides pater*). The myriopods, of which thirty-five species have been recorded, are treated with especial care, being represented in Permian times by a greater number of distinct families than at the present day. The discovery that they possessed three simple thoracic segments is very important. The Arachnida were represented by Tetrapneumonous spiders, and the Merostomata by *Prælimulus Woodwardi*, a *Limulus* with simple extremities to its legs. The Entomostraca have long been determined with the valuable assistance of Professor T. Rupert Jones, and the plates show that in some specimens the soft parts and internal structures of the animal have been preserved within the test, and even embryos. To the systematic worker in the Malacostraca the restored figure of *Gampsonyx* from Lebach will be of the greatest interest, as it shows that this Crustacean was not provided with bifurcated appendages, like *Mysis*, but with simple ones. A new genus of Crustaceans, *Gasocaris* (a rather barbarous name), has also seven equal pairs of simple legs, and forms with

Gampsonyx and the American genus *Acanthotelson* a new suborder—Simplicipoda.

In a supplement, Dr. Anton Fritsch introduces the figure of a true reptile, *Naosaurus*, which, like the American species from the Permian of Texas, possessed lateral spines attached to the long neurapophyses of the vertebral column. Amongst the new Stegocephalia is a very fine skeleton of the remarkable genus *Ptyonius*.

It is not too much to say that during the past century no single worker has produced a monograph on Palæozoic palæontology of equal importance. We are glad to be able to record that the value of Dr. Fritsch's labours has been recognized by the Council of the Geological Society of London, who awarded him the Lyell Geological Fund in 1881, on the issue of the author's first volume; whilst the Paris Academy presented Dr. Fritsch with the Cuvier Prize on the completion of his great work. We feel sure that all palæontologists will rejoice to see the completion of this important monograph, and will join with us in complimenting its author on the successful termination of his arduous labours.

II.—Geology of the South African Republic of the Transvaal. By G. A. F. Molengraaf. Bull. Soc. Géol. de France (4), 1901, i, pp. 13–92, 19 text-figures and 2 plates. Pl. i: Geological Sketch at 1 : 1,500,000. Pl. ii: Geological Sections.

THE geological researches in the Transvaal are considerably favoured by the dry and mild climate and the scarce vegetation, as well as by the simplicity of the structure of the country. The greatest drawback is the absence of determinable fossils in the sedimentary formations, with the exception of the Upper Karroo. The geological map must therefore be considered as a mere diagrammatical sketch.

Viewed in the abstract, after passing the Jurassic, Cretaceous, and more recent formations near the littoral, the chief rocks of the Transvaal are as follows, in descending order:—

III. The Karroo System.
II. The Cape System.
I. The Primary South African System.

This classification had already been adopted by Bain for the Cape Colony and by Schenk for the whole of South Africa.

I. Primary South African System.

The Primary South African System is composed of stratified deposits associated with numerous intrusive massifs of granite; the structure of the former has been subjected to contact-metamorphism produced by the intrusion of the latter.

The gold-mines are chiefly in the Primary System and in the neighbourhood of Barberton; the series of the famous Witwatersrand has been calculated by De Launay at 7,500 metres. The gold is mostly found in the conglomerates, there being much less in the quartzites.

The age of the Primary South African system is unknown. In the Cape Colony, however, an undoubtedly Devonian formation

overlies unconformably the Malmesbury Series and the massifs of granite by which it is traversed. The Malmesbury Series being part of the Primary South African System, this last must be Pre-Devonian, viz. either Silurian or Pre-Cambrian.

II. Cape System.

The Cape System is composed of the following divisions, enumerated from above downwards:—

5. Series of the Waterberg Sandstone.
4. Plutonic Series of the Boschveld.
3. Pretoria Series.
2. Series of the Dolomites.
1. Series of the Black-reef.

The Bokkeveld strata of Cape Colony, corresponding to the Dolomites of the Transvaal, are the only deposits anterior to the Karroo System in which fossils—marine organisms of the Lower Devonian—have been found.

The physical features of the deposits where the Dolomites predominate offer a great resemblance to the Austrian Karst. Caves are frequent, many of them being ossiferous; the organic remains have not, up to the present, been studied. In many places rivulets, penetrating through fissures at the surface, form subterranean watercourses and lakes, and reappear again in the form of numerous and voluminous watercourses, which scarcely diminish during the dry season. To these remarkable constant sources of supply almost all the perennial rivers of the Western Transvaal owe their existence.

III. Karroo System.

In the Transvaal the Karroo System rests unconformably on the before-mentioned older formations, and generally in a horizontal position. Two primary subdivisions are to be distinguished, the *Lower* and the *Upper Karroo*.

1. *Lower Karroo.*

Generally speaking, the strata of the Lower Karroo are horizontal, although following more or less the undulations of the ground. In the whole of South Africa geologists have adopted the subdivision of the Lower Karroo into two *étages*, viz. the *Dwyka Conglomerate* and the *Ecca strata*.

The author adheres to the opinion of those geologists (Sutherland, Griesbach, Stow, Schenk, etc.) who consider these two *étages* as deposits of undoubtedly glacial origin, probably of the Permian period. We must be prepared to find all the phenomena of a prolonged glacial action in much larger and more imposing proportions than the *diluvium* of the Northern Hemisphere.

The problem of the glaciation of South Africa, during the Permo-Carboniferous period, presents more than a local interest. The geological researches in India and Australia have shown that in these countries formations exist of striking analogy. In India the *Gondwana* System may be identified with the system of the Karroo.

At its base are found the *Talchir Conglomerates*, absolutely comparable with the *Dwyka Conglomerate*. The older underlying rocks (*Vindhyan limestones*) have been found to be polished and striated in various localities, e.g. near Chanda in the Central Provinces of India. The *Talchir shales* are associated with this conglomerate; they offer all the characters of the Ecca strata, and like the latter they are almost everywhere devoid of fossils. On these glacial deposits rest sandstones comparable to the sandstone of the Upper Karroo, and in which has been found a *Glossopteris* flora, very similar to that of the Karroo.

In Australia the traces of an ancient glaciation are not less evident, and the glacial deposits which there also, as in the Salt Range of India, are associated with sediments containing marine fossils, show that the glaciation of these two continents was contemporaneous and took place during the last period of the Palæozoic era. Moreover, the general affinities between the *Karroo* and the *Gondwana* System are so evident that we must admit the contemporaneity of the Permian glacial deposits in South Africa, India, and Australia.

2. *Upper Karroo.*

The strata of the Upper Karroo are almost everywhere found in a normal and horizontal position; they are composed of sandstones, argillites, arenaceous argillites, Carboniferous clays, and Carboniferous strata.

Horizon of the Coal.—In the Upper Karroo of the Transvaal, provisionally called by the author the *Hoogeveld formation*, are found the Carboniferous strata which, on account of the continual increase of the Witwatersrand mining industry, must prove a great wealth to the country. The deposits are immense: the coal-mines of the Transvaal will certainly supply the demands of the whole of Africa for at least a hundred years.

The Carboniferous strata of the Transvaal seem to be vegetable alluvia, deposited by the action of torrents. Fragments of trunks of *Sigillaria*, and trunks, branches, and leaves of several species of *Glossopteris*, largely compose these coal-beds.

The mode of formation of the Upper Karroo may be imagined to have taken place in the following manner. After the retreat of the glaciers the *paysage morainique* predominated in this region, where the Dwyka Conglomerate was in a great measure covered, and on all sides surrounded, by the Ecca strata. Erosion soon began to exercise its destructive action, and the Lower Karroo deposits were doubtless, in places, completely *remaniés*; at the same time a series of sediments, constituting the Upper Karroo, were being deposited. These fresh-water deposits were accumulated partly in the watercourses, partly in the lakes; they were made up of obliquely stratified sandstones and clays, and sometimes also of strata of plant-remains, transported by the torrents; the latter strata have become the present Carboniferous beds. Only a small portion of the enormously developed Karroo System has been

preserved, the remainder having been destroyed during the period of denudation following its formation; this period continues at the present day.

As to the age of these deposits, the researches of Seward and Zeiller on the plant-remains have shown that the lower *étage* of the Upper Karroo of the Transvaal is of Permo-Carboniferous age.

The wording of the title of the paper here reviewed is somewhat surprising. We remember that the author figured as delegate of the "South African Republic" at last year's International Geological Congress. But then the Congress was somehow connected with the Exhibition. In the present instance we are sorry to state that a scientific society does not refrain from imparting a political bias to a purely scientific paper, which, coupled with the expressions of the President of the French Geological Society when welcoming the author (p. 9), seems hardly friendly towards this country.

CORRESPONDENCE.

JURASSIC BRACHIOPODA.

Sir,—May I beg a little of your valuable space to make a correction in my paper "Homœomorphy among Jurassic Brachiopoda" (Proc. Cotteswold Nat. F.C., vol. xii). Therein I have figured and described a new species as *Zeilleria subcornuta*, the specific name being the same as was used between Dr. Davidson and myself twenty years ago in correspondence about the same shell. But there is already a *subcornuta* used by Quenstedt, and it would also be *Zeilleria subcornuta*. Wherefore I desire to change the name of my species to *Zeilleria cornutiformis*. I would take this opportunity to thank you for your kindly notice of this paper, but may I ask if your reviewer has quite separated "time-table" from a table of strata when he surmises that perhaps I claim no more than a local value for my "elaborate time-table." Certainly I made no definite claim; but I own to thinking that a time-table, as such, is of worldwide application. There is no local limit to time, and there can be no local limit to a time-table. Whether the records of the rocks in distant localities may be sufficiently perfect to enable their dates to be stated with as great exactitude as in my time-table, is another matter. But the table of strata which I have given in connection with this time-table shows that from Yorkshire to Dorset, from Dorset to Würtemberg, the time-table is a means of exactly dating Jurassic events; therefore it has much more than a local value. But in that table I gave the results of only my own work, and refrained, except in one or two striking instances, from quoting literature. Had I done so, it would have shown even more clearly that the time-table is a means whereby Jurassic events over a large part of Europe can be exactly dated now; and there is good reason to think that the same may be said of a far wider field in the future.

S. S. Buckman.

FOSSILS AND GARNETS.

SIR,—On p. 165 of the current volume of this Magazine we read that to the writer of the article there printed "it is very difficult to understand how such a fossil as a belemnite could have retained its characteristic form while molecular changes of such importance were taking place in the matrix of the rock . . . . The results of contact-metamorphism most nearly resemble the crystalline schists. In them, so far as my [the writer's] experience goes, garnet, and still more staurolite, are not formed until the materials of the rock have undergone such great molecular changes as to obliterate all traces of a sedimentary origin" . . . .

On p. 140 of "Études Synthetiques de Géologie expérimentale par A. Daubrée," dated 1879, we read statements which when translated into English are to the following effect:—

"It is well known that the crystallization that is brought about by the proximity of eruptive rocks has not always effaced the traces of the fossils. There still remain very distinct vestiges of them in the middle of rocks crowded with crystalline silicates. One need only recall the fossiliferous Silurian limestone of Norway, which contains at Brevig paranthine and garnet, and at Gjellebeck amphibole and epidote . . . . and lastly, in the Vosges the amphibole rock of Rothau, in which the corals have been replaced, without being deformed, by crystals of amphibole, garnet, and axinite. In some places the rock now consists entirely of a mixture of lamellar pyroxene, epidote, and compact garnet, with flecks of galena. In the middle of this rock, composed entirely of silicates of this nature, I have recognized perfectly preserved impressions of numerous corals (more especially of *Calamopora spongites*, Goldf.) and Flustras . . . . More than this, the very cavities left by the partial disappearance of the calcareous matter of these corals are lined with crystals of the same minerals as form the bulk of the rock . . . .

"Now it is the same thing in the case of the crystalline masses we are considering . . . . MM. Lardy and Strider have found in the neighbourhood of St. Gotthard belemnites in the middle of micaceous schists with garnets." VERBUM SAP.

OBITUARY.

JOHN STORRIE, A.L.S.

BORN 1844. DIED MAY 2, 1901.

JOHN STORRIE, for many years Curator of the Cardiff Museum, and an earnest worker at the natural history of Glamorganshire, was born at Muiryett, in Lanarkshire. His early years were spent at Glasgow, where he was apprenticed to the printing-trade, and about the year 1872 he found employment in the *Western Mail* printing works at Cardiff. The writings of David Page had given to Storrie an interest in geology, and he pursued the subject with zeal when he came to reside in South Wales. The Silurian rocks of